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CYLINDER CONDENSATION IN STEAM ENGINES. AN EXPERIMENTAL INVESTIGATION.

BY CHAS. L. GATELY, M. E., AND ALVIN P. KLETZSCH, M. E.

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[*Concluded from November Issue, page 346.*]

CHAPTER IV.

19. CALCULATION AND LAW OF CASE I.

The foregoing logs and Table No. 1 have reference to the experiments in which the cut-off was varied.

The experiments are four in number, and the apparent cut-off taken corresponded approximately to one-eighth, one-third, one-half, and five-eighths, these being deemed a sufficient number in order to permit of the forming of an expression containing the per cent. of cut-off as a variable.

From Table 1, it will be seen that the true cut-offs, as calculated from the card, are ·131, ·330, ·443 and ·589, corresponding respectively to the apparent cut-offs above mentioned. After averaging the logs and placing the same in suitable shape for use, the data

to be determined from the indicator-cards was calculated. For this purpose, blanks were ruled so as to contain:

The area of cards in square inches;
The real cut-off in inches;
The apparent cut-off in inches;
Pressure at cut-off in inches;
Pressure at release in inches;
Real volume at release in inches;
Length of indicator diagram in inches.

After averaging the results of each test for all the cards, both of the outer and inner cylinder, they were reduced to:

Mean effective pressure.

Per cent. of real and apparent cut-off per length of stroke and initial pressure of the steam in pounds per square inch on the piston and pressure of the steam in pounds on the square inch, at the opening of exhaust and their values entered in Table 1.

To determine the amount of condensation of steam in the steam engine cylinder, up to the point of cut-off, the difference was taken between the amount of water pumped into the boiler as calculated from the weir and the amount shown by the cards up to the point of cut-off. The ratio of this quantity to the true amount will be the per cent. of cylinder condensation up to the point of cutting off the steam. The method of deducing the amount of feed water pumped into the boilers as calculated from the thermal units of the weir will be described below. The meter readings in this case were of no account, for the reason already mentioned, namely, that three boilers were used while the meter indicated the amount for two of them. The per cent. of condensation, as determined, increases as the ratio of expansion increases.

Plate I will serve to show the final results more clearly. The ordinates representing per cent. of cut-off in length of stroke and the abscisses the amount of condensation expressed in per cent. of the total amount of steam furnished to the engine.

20. GENERAL METHOD OF CALCULATION AND OF DEDUCTION OF LAW OF CONDENSATION, WITH VARYING RATIOS OF EXPANSION—USE OF GRAPHICAL METHOD.

In the annexed table, will be found the observed data and the

calculated results of the experiments made with the engine, and in the manner precedingly described for variable cut-off.

(*See Table No. 1.*)

The experiments were four in number, and the results are arranged in parallel columns under their respective cut-offs, namely, ·589, 443, ·330 and ·131 of the length of the piston stroke. A smaller ratio of expansion could not well be obtained on account of the size of the boilers, these not being able to supply the demand for steam made upon them by the engine when subjected to a greater load.

For facility of reference, the quantities as far as practicable are arranged in groups, and the lines composing them numbered.

Time.—Lines 1 and 2 contain the date and time of beginning and concluding of each of the tests, and line 3, the duration in consecutive minutes.

Total Quantities.—Line 4 contains the number of double strokes made by the piston, obtained by subtracting the indications of the counter at the beginning from the reading at the completion of the test. Line 5 contains the total quantity of feed water pumped into the boilers, as calculated from the rise in temperature of the condensing water which flowed over the weir.

It is obtained by dividing the total number of heat units as calculated from the weir, together with the heat units due to radiation, and those converted into work by the heat units in one pound of the steam at the pressure of the boiler, corrected for the heat units due to the water of priming, minus the heat in one pound of the water of condensation. It will be seen, thus, that the weir, at least in this case, came in to good advantage, as without it and with insufficient meter readings, the tests in this case could certainly not have been used.

Line 6 contains the number of pounds of feed water pumped into the boilers per hour, and is found by dividing the total pounds of feed water on line 5 by the duration of the test in hours.

Line 7 gives the average height of the water flowing over the notch. By means of the partitions placed in the tumbling-bay and the perforations in the last one, the water passed in a steady flow under the pointer, attached to the micrometer screw, so that nothing interfered to ascertain the correct reading of the micrometer scale.

Line 8 are the number of double strokes made by the engine piston per minute, and are the quotients of the division of the quantities on line 4 by the quantities on line 3.

Line 9 is the observed vacuum in inches of mercury per gauge, and each test represents the average of the readings taken.

Line 10 contains the mean boiler pressure in pounds per square inch above the atmosphere, as per gauge.

Line 11 and 12 contain the steam pressure in the cylinder in pounds per square inch above absolute zero, or point of no pressure of the atmosphere, at the point of cutting off the steam and at the opening of release. Line 13 contains the mean gross effective pressure of the steam upon the face of the piston during its stroke. These quantities were taken from the indicator diagram. Those on lines 11 and 12, by direct measurement and then by multiplying them by the scale of spring used in the indicators during the test.

The mean gross effective pressures on line 13 were obtained by multiplying the average area of the cards in square inches by the scale of the spring used, and dividing the product by the average length of card taken. The area of the cards, in square inches, was obtained by means of J. Amsler-Laffon polar-planimeter, undoubtedly the best for its construction and accuracy, known to the present engineers.

Line 14 contains the pressure on the square inch required to work the engine by itself, and was obtained from the friction cards taken from the engine for this purpose.

Line 15 contains the mean net effective pressure in pounds per square inch on the piston, and is the difference between the quantities on lines 13 and 14.

Line 16 is the per cent. which the quantity on line 15 is of the quantity on line 13.

Line 17 contains the gross effective horse-power of 33,000 foot pounds raised one foot high, developed by the engine and calculated for the mean gross effective pressure on line 13, the number of double strokes on line 7 of each test and the distance travelled by the piston while making one stroke, namely, seven feet.

Line 18 contains the net horse-power usefully applied, and is calculated from the piston pressures on line 15, and for the speed of piston on line 8.

Line 19 contains the number of pounds of feed water consumed

per hour per gross effective horse-power. These weights are the quotient of the division of the quantities on line 6 by the quantities on line 17.

Line 20 contains the number of pounds of feed water consumed per hour per net effective horse-power, and is the quotient of the quantities on line 6 by the quantities on line 18.

Temperatures.—Line 21 contains the average temperature of the injection water. This was nearly constant for each test, owing to the large body of water from which it was drawn and to the depth of the pipe below the ground.

Line 22 contains the average temperature of the weir during each trial. No difficulty whatever was experienced in obtaining this temperature, when holding the thermometer in the water where leaving the notch, allowing it to strike the bulb. Thus, giving at the same time not only the true reading, but also preventing an undue eddy being produced in the weir, which would have affected the readings of the micrometer scale taken at the same time. Line 23 contains the temperatures of the feed water, taken after the water had left the meter. Sufficient water was allowed to pass through the meter in order not to be affected by direct connection with the pipe, etc. This temperature was usually taken while the water was fed to the boilers used in the trials. As far as the third boiler would permit a continual stream was fed into the boilers, in order to keep the boilers as much as possible at the same level.

Line 24 contains the per cent. of the amount of feed water that passed into the cylinder from the boilers, in the form of water, entrained in the steam, due to incomplete evaporation. The following is the method in detail in which these tests were made, and the manner of arriving at the result:

The weight of the calorimeter empty was first taken. Seventy pounds of water of known temperature t'', was then introduced, this being a convenient figure to handle, and about the capacity of the tank. The three-way cock connecting the worm of the calorimeter with the pipe leading to the boiler was then opened, and steam allowed to flow into the air until the connections were of the same temperature as the steam, and the time of flow noted. The cock was then turned, and the steam flowed into the calorimeter, heating the seventy pounds of condensing water $= W$ up

to any observed temperature t', the whole volume of water being well agitated, so as to equalize the temperature. The time of the latter flow was noted and the boiler pressure recorded.

Let W = the weight of condensing water;
w = the weight of wet steam;
t'' = initial temperature;
t' = final temperature;
$R = t' - t''$ = range of temperature;
t = heat units in one pound of water at the boiler pressure;
x = steam run into calorimeter;
$U = W \times R$ = heat units transferred to calorimeter;
$H = T - t'$ = heat from steam;
$h = t' - t''$ = heat from water;
y = percentage of priming; we then have Dr. Thurston's equation*

$$Hx + h(w - x) = U.$$

And solving for x

$$x = \frac{U - hw}{H - h} \quad : \quad y = \frac{w - x}{w}.$$

The time of flow in air and in the calorimeter is given so as to calculate the amount to be deducted from the feed water reading, due to loss from this cause. Thus, in Test 1, flow in air, 1 minute; in calorimeter, 2½ minutes. We see that the weight which flowed into the calorimeter in this time is 5⅜ pounds, or 2·15 per minute; therefore, 3½ times 2·15 will give the total amount to be subtracted in this case = 7·525 pounds, nearly. The heat units, in all cases, were interpolated from Porter's tables.

Line 25 contains the total number of pounds of steam in the cylinder up to the point of cutting off the steam. It is calculated for the weight of one cubic foot of steam at the pressure of cut-off, as given in Porter's tables, into the piston displacement, due allowance being made for clearance and piston rod. Thus, if W = total number of pounds of steam at cut-off, we would have, for one end,

$$W = (V C + V') N w T$$

where V = volume of the end of cylinder in cubic feet.

*American Institute Report on Steam Boilers, 1871, p. 17.

V' = clearance of the end in question;
N = number of revolutions per minute;
C = per cent. of stroke at which steam is cut off;
w = weight of one cubic foot of the steam in decimals of a pound, corresponding to the average pressure in the cylinder; and
T = duration of trial in minutes.

The weight of the steam thus calculated was evaporated from and at the temperature of the feed water.

Line 26 contains the number of pounds of steam in the cylinder at cut-off at the end of one hour, and calculated from the pressure in the cylinder at the point of cutting off the steam. It is the quotient of the division of the quantities on line 25 by the duration of the trial expressed in hours.

Line 27 contains the total pounds of steam in the cylinder at release, calculated from the pressure of the steam in the cylinder, immediately before the opening of the exhaust. The calculation is in all respects similar to the calculations of line 25, substituting for c the length of stroke completed up to the opening of the exhaust.

Line 28 contains the total number of thermal units in the steam as calculated from the feed water consumed. As the total number of thermal units passed into the engine is the sum of the quantities of the heat expended, we have for the whole number of thermal units: the thermal units shown at exhaust plus the number due the energy expended in driving the engine, and its controlling apparatus plus that due to radiation and conduction. The quantities in line 28 are the sum of these three forms of expended heat.

Line 29 contains the total number of heat units accounted for by the weir. Knowing the average height of flow over the notch board, the number of cubic feet of water which have passed through the condenser can easily be calculated by means of the usual formula.

$$Q = \tfrac{2}{3}\, c\, b\, h\, \sqrt{2\, g\, h}$$

or, when c and b are known, as in this case, then

$$Q'' = 1{\cdot}6673\, h^{\frac{3}{2}}$$

where Q = flow in cubic feet per second;
h = average height of water in inches over notch;

b = breadth of notch in inches;

c = coefficient of contraction.

Substituting for h the average height determined as per experiment, and multiplying by the time of flow in seconds, the number of cubic feet are determined at the temperature of the trial. Knowing the weight of one cubic foot of water at the temperature given by the weir, and the thermal units in one pound of the water at the temperatures of the weir and injection, the thermal units in line 29 are easily determined. Let Q as before represent flow in cubic feet per second.

T = duration of test in seconds;

W = weight of one cubic foot of the condensing water and wet steam;

H = heat units in one pound of the condensing water at the final temperature, and

h = heat units in one pound of the injection water, then

$B\ T\ U$ the total units of heat contained on line 29 becomes

$$B\ T\ U = Q\ T\ W\ (H - h).$$

Line 30 contains the total number of thermal units as per weir per hour. It is the quotient obtained by the division of the quantities on line 29 by the duration of the trials in hours.

Line 31 contains the per cent. of the steam evaporated in the boilers, not accounted for by the indicator at cut-off. Line 6 giving the water actually consumed per hour by the engine, and line 26 being the amount indicated by the diagrams, the difference is the amount not accounted for by the indicator, existing in the form of water in the cylinder. The per cent. which the quantity is of line 6, is the amount of condensation in the steam engine cylinder, to the point of cutting off the steam.

Knowing the percentage of condensation for the various ratios of expansion as determined in these trials, and in order to readily determine the amount of condensation for other points of cut-off, the results have been plotted, the locus of the curve showing the per cent. of cylinder condensation for the ratios of expansion under which the engine may be run. (*Plate I.*)

21. CALCULATIONS IN DETAIL—RESULTS DISCUSSED AND CLASSIFIED—FINAL EXPRESSIONS AND CURVES REPRESENTING THEM.

On examining Table 1, it will be found that the conditions

CASE I.—CONDENSING.—VARIABLE CUT-OFF.

Table No. 1.—Containing the Data and Results of Experiments made at Sandy Hook, Conn., to determine the Laws of Cylinder Condensation.

Number of Line.			Fraction of the Stroke of Piston completed when Steam was Cut off.			
			·589	·443	·330	·131
1	Time.	Date of commencing experiment,	A. M. 11·32, May 25.	P. M. 2·04, May 25.	P. M. 2·36, May 24.	A. M. 10·16, May 24.
2	Time.	Date of ending experiment,	P. M. 1·02, May 25.	P. M. 4·04, May 25.	P. M. 4·31, May 24.	P. M. 12·16, May 24.
3	Time.	Duration of experiment in consecutive minutes,	90	120	115	120
4	Total Quantities.	Number of double strokes made by the engine piston, per counter,	6144	8095	7741	8274
5	Total Quantities.	Number of pounds of feed water pumped into boilers, per weir,	8788·5	10222·4	7331·5	3375·5
6	Total Quantities.	Number of pounds of feed water pumped into boilers, per weir, per hour,	5859·	5111·2	38 5·1	1687·75
7	Total Quantities.	Average height of water over weir, in inches,	4·474	4·0161	3·195	2 2782
8	Engine	Number of double strokes made per minute by the engine piston,	68·26	67·45	67 32	68·95
9	Engine	Vacuum in condenser in inches of mercury, per gauge,	21·43	22·C6	20 95	22·61
10	STEAM PRESSURES In Cylinder per Indicator.	In pounds per square inch above atmosphere in boilers, per gauge,	56·83	61·28	60·1	61·1
11	STEAM PRESSURES In Cylinder per Indicator.	In pounds per square inch above zero at cutting off the steam,	61·54	68·34	62·10	49·11
12	STEAM PRESSURES In Cylinder per Indicator.	In pounds per square inch above zero at release,	38·28	32·03	21·05	8·47
13	STEAM PRESSURES In Cylinder per Indicator.	Mean gross effective pressure in pounds per square inch on piston,	47·94	47·11	36·03	19 36
14	STEAM PRESSURES In Cylinder per Indicator.	Pressure in pounds on the square inch required to work the engine,	3·5	3·5	3 5	3·5
15	STEAM PRESSURES In Cylinder per Indicator.	Mean net effective pressure in pounds per square inch on piston during its stroke,	44·44	43·61	32·53	15·86
16	STEAM PRESSURES In Cylinder per Indicator.	Per cent. of which the mean net effective pressure is of the mean gross effective pressure,	92·69	92·57	90·16	81·92
17	POWER. Absolute.	Gross effective horses-power, developed by the engine,	174·589	169·474	129·420	52·158
18	POWER. Absolute.	Net horses-power, usefully applied,	162 82	156·86	116·625	42 728
19	POWER. Economic.	Pounds of feed water consumed per hour, per gross effective P.	33·25	30·16	29·53	32·35
20	POWER. Economic.	Pounds of feed water consumed per hour, per net effective P.,	35·98	32·58	32·78	39·49
21	Temperature in Deg. Fahr.	Of the injection water,	69·	67·7	71·6	67·1
22	Temperature in Deg. Fahr.	Of the water in the weir,	131·9	131·44	135·7	116·3
23	Temperature in Deg. Fahr.	Of the feed water,	. . . . .	114·	140	114·3
24		Per cent. of the amount of feed water, that passes into the cylinder from the boilers in the form of water entrained in the steam, due to incomplete evaporation,	5·22	5·68	7·86	7·69
25		Total pounds of steam in the cylinder at cut-off, calculated from the pressure of the steam in the cylinder at the point of cut-off,	6790·251	7454·477	4847·418	1685·159
26		Pounds of steam in the cylinder at cut-off: calculated from the pressure of the steam in the cylinder at the point of cut-off at the end of one hour,	4526 834	3727 24	2529 24	842·579
27		Total pounds of steam in the cylinder at release; calculated from the pressure of the steam in the cylinder at release, immediately before the opening of exhaust,	6902·309	7805·352	5049·612	2288·183
28		Tot l number of thermal units in the steam expended by the engine, as calculated from the feed water consumed,	9031477·5	10481821·8	7340169·	3451899·8
29		Total number of thermal units, as per weir,	7920754 6	9113387 6	6354643 1	3018080·5
30		Total number of thermal units, as per weir, per hour,	5280503·	4556094·	3631225·	1509040·
31		Per cent. of the steam evaporated in the boilers, not accounted for by the indicator at cut-off,	22 73	27 08	33 87	50·07

intended to have been kept constant during the trials vary somewhat.

The distances travelled by the engine piston in the tests of Case I, does not vary more than seven feet per minute from the average and the difference between the greatest and lowest speed during the trials amounts to but thirteen feet per minute. When taking into account the controlling power of the engine, the degree with which the pulley heated and consequent expansion of its rim a fluctuation of from one to two and a-half per cent. at the greatest could, with the limited amount of time and assistance, hardly be avoided. The steam pressures as recorded per boiler gauge also show some fluctuation; this, however, was not due to any inexperience in firing, but to the greater demand made by the engine upon the boilers than these were originally intended for. As the work of the engine came down to its ordinary conditions; that is, to the capacity of the boilers, a more uniform boiler pressure was obtained, varying not more than one and a-half per cent. between the highest and lowest pressures, while the difference in the whole range amounts to but five per cent. of the highest boiler pressure recorded. As shown in our later tests, condensation changing slowly with the initial pressures, the difference due to a slight variation of the boiler pressure, would not appreciably affect the law of condensation at the varying cut-offs of ·589 and ·443, respectively.

Having discussed the two constant factors and their slight variation during the tests of Case I, the per cent. of cut-off per length of stroke, and the amount of condensation, can now be taken into consideration.

From Table No. 1, we have for a

Cut-off of ·589;	cylinder condensation	= 22·73 per cent.
·443;		= 27·08
·330;		= 33·87
·131;		= 50·07

from which we see that the condensation increases rapidly with expansion of steam; or, in other words, with longer exposure of the sides of the cylinder, cylinder head and piston, to the decreasing temperatures of the expanding steam.

Plotting these results upon paper and making the abscisses represent the amount of condensation, or the per cent. of the total steam condensed in the steam engine cylinder, excepting that due

to the priming, and letting the ordinates represent the fraction of the stroke completed when the steam was cut off, and tracing the curve through the points of intersection we obtain the curve as represented in *Plate I.*

22. METHOD OF DEDUCING ALGEBRAIC EXPRESSIONS FOR VARIATION OF CONDENSATION IN CASE I, AND FUNCTIONS OF SIZE OF ENGINE AND AREA OF SURFACE EXPOSED.

Taking the actual figures in Table I, as found by experiment for cut-off and cylinder condensation, and an intermediate point from the curve between the cut-offs of ·131 and ·330, we have for

Cut-off $= y =$ ·131	condensation $= x =$ 50·
·225	= 41·
·33	= 34·
·45	= 27·
·59	= 22·5

The locus of these points appearing to follow an hyperbolic expression, we applied the general equation of an hyperbola.

$$(x + a)(y + b) = c, \text{ or}$$
$$xy + bx + ab = c.$$

Transposing, we have

$$bx + ay - c = -xy,$$

and substituting the above values for x and y, we have

$$50\,b + \cdot 13\,a - c = -\cdot 0650 \quad (1)$$
$$34\,b + \cdot 33\,a - c = -\cdot 11225 \quad (2)$$
$$22\cdot 5\,b + \cdot 59\,a - c = -\cdot 13275 \quad (3)$$

Equating (1) and (2) and eliminating c, we have

$$\cdot 16\,b - \cdot 20\,a = \cdot 04725 \quad (4)$$

and performing the same operation with equation (1) and (3), we have

$$\cdot 275\,b - 46\,a = \cdot 06775 \quad (5)$$

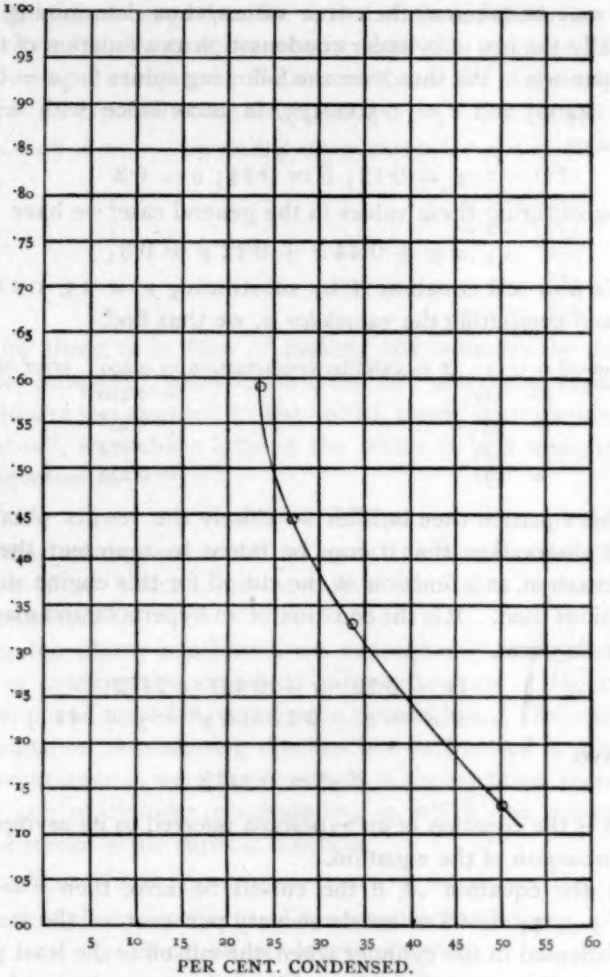
We now have two equations with two unknown quantities, eliminating a from these by the ordinary rules of algebra, we have

$$\cdot 0186\,b = \cdot 008185$$
$$b = 44005$$

Substituting the value of b in (4), we have

$$\cdot 0704 - \cdot 20\,a = \cdot 04725$$
$$\cdot 20\,a = \cdot 02315$$
$$a = \cdot 11575$$

PLATE I.



CONDENSATION WITH BOILER PRESSURE VARIABLE.

and by substituting the values for a and b in (1), we have

$$\cdot 22 + 0150475 - c = -\cdot 0650$$

$$\text{and } c = \cdot 3000475$$

As the values of a, b and c, when calculated by the other of the original equations, differ only in the fifth and sixth decimal places from the results obtained above, these values for the

coefficients of x and y in the hyperbolic equation, and of the constant may be taken as their true values, thus determining experimentally the law of cylinder condensation as a function of the ratio of expansion. We thus have the following values for $a = 0{\cdot}11575$, $b = 0{\cdot}44005$ and $c = 0{\cdot}3000475$, in accordance with which we will take

$$a = 0{\cdot}12\,;\ b = 0{\cdot}44\,;\ c = 0{\cdot}3$$

and substituting these values in the general case, we have

$$x\,y + 0{\cdot}44\,x + 0{\cdot}12\,y = 0{\cdot}3 \qquad A.$$

We now test equation A, by substituting $y = {\cdot}13$, $0{\cdot}225$, $0{\cdot}33$, etc., and computing the values for x, we thus find,

y = cut-off = $0{\cdot}13$;	x = cylinder condensation = $0{\cdot}499$;	error of $-\ 0{\cdot}001$
= ·225;	= $0{\cdot}410$;	$0{\cdot}000$
= ·33;	= $0{\cdot}338$;	$-\ 0{\cdot}002$
= ·45;	= $0{\cdot}274$;	$+\ 0{\cdot}004$
= ·59;	= $0{\cdot}222$;	$+\ 0{\cdot}002$

This equation then satisfies so closely the results obtained by direct observation, that it may be taken to represent the law of condensation, as a function of the cut-off for this engine under the conditions used. It is the equation of an hyperbola and may be put under the form,

$$(x + 0{\cdot}12)\,(y + 0{\cdot}44) = {\cdot}2472 \qquad B$$

or if $x' = x + 0{\cdot}12$ and $y' = y + {\cdot}44$

we have

$$x'\,y' = 0{\cdot}2472$$

which is the equation of an hyperbola referred to its asymptotes.

Discussion of the equation.

In the equation A, if the cut-off be zero, then $y = 0$, and $x = {\cdot}3 \pm 44 = {\cdot}68$ or nearly seventy per cent. of the steam will be condensed in the cylinder when the cut-off is the least possible.

If we allow steam to follow full stroke, $y = 1{\cdot}0$, and we find $x = {\cdot}12$, or at full stroke twelve per cent. of the steam will be condensed in this engine. These latter conclusions are, however, of less value, because they result from extending an empirical formula too far beyond the limits of the experiments, or which it is founded in both directions.

As a matter of curiosity, we notice that equation B shows that when the cut-off is $-\ 0{\cdot}44$, the condensation will be infinite.

Cylinder condensation as function of area exposed. The area of cylinder surface exposed to the action of the initial steam varying directly as the cut-off, we obtain from the curve of *Plate I*, when allowing z to represent the area in square feet of the cylinder, and its piston exposed to the steam, for a

Cut-off of ·6;	square feet of area exposed	$= z = 13{\cdot}86$
·5;		$= z = 12{\cdot}21$
·4;		$= z = 10{\cdot}56$
·3;		$= z = 8{\cdot}91$
·2;		$= z = 7{\cdot}26$
·1;		$= z = 5{\cdot}61$
·0;		$= z = 3{\cdot}96$

Plotting these, as in *Plate II*, making the ordinates the fraction of stroke completed, when steam is cut off; and the abscisses the area in square feet exposed to the initial steam, corresponding to these cut-offs, we find the locus of the points to be a straight line, whose equation is,

$$x = 3{\cdot}96 + 16{\cdot}5\, z;$$

that is, the area exposed to the action of the steam varies directly as the cut-off, as it should, as increase of admission increases the surface exposed.

From the above conclusion, we consequently infer that the amount of condensation expressed as some function of the area of surface exposed, must follow the same general law. The constants of the equation representing this law, are determined in precisely the same manner as were the constants in the equation representing the law of cylinder condensation, in which the cut-off per length of stroke is the variable function.

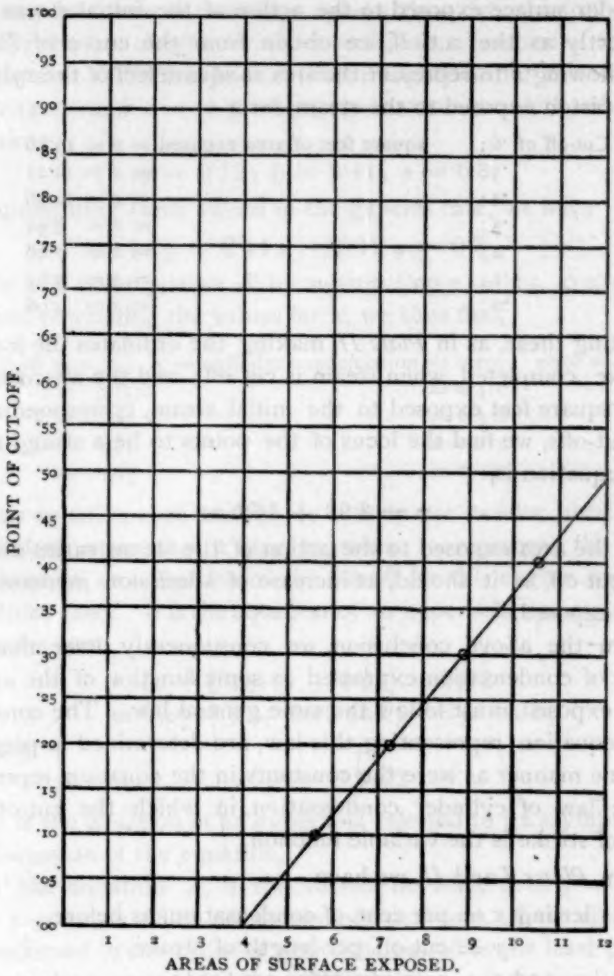
From *Plates I* and *II*, we have

letting $x =$ per cent. of condensation, as before,
$y =$ cut-off per length of stroke,
and $z =$ area of surface exposed:

$x = 22{\cdot}4$;	$y = {\cdot}6$;	$z = 13{\cdot}86$ square feet.
$25{\cdot}$;	·5;	12·21
$28{\cdot}5$;	·4;	10·56
$36{\cdot}$;	·3;	8·91
$44{\cdot}$;	·2;	7·26
$53{\cdot}5$;	·1;	5·61
$68{\cdot}1$;	·0;	3·96

and representing the ordinates for this new curve by the value of

PLATE II.



CONDENSATION WITH VARIABLE AREAS EXPOSED.

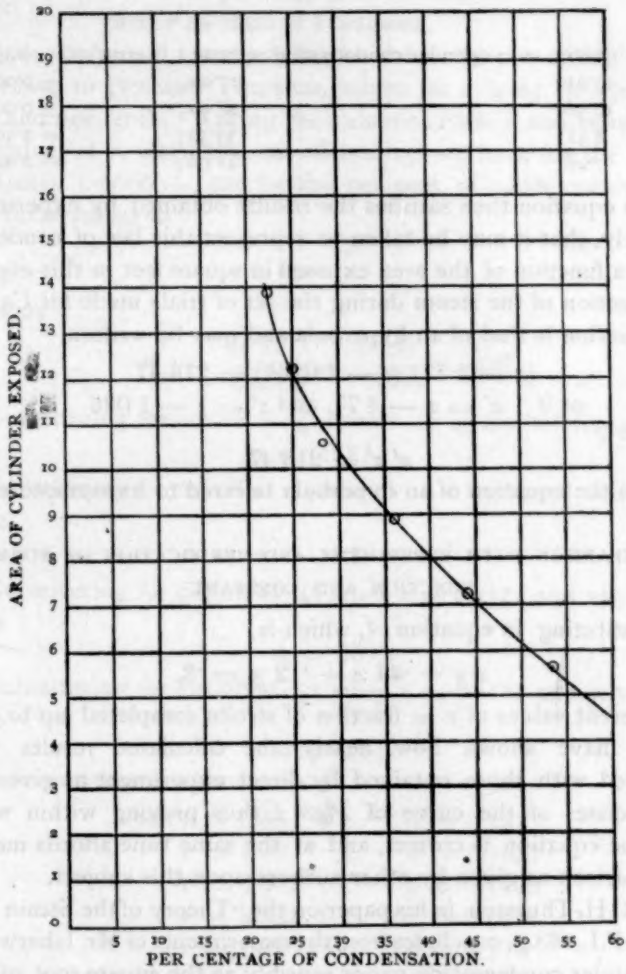
z, and the abscisses the corresponding cylinder condensation, we find the locus of the curve, represented on *Plate III*, to have the same general appearance of the curve of *Plate I.*

We infer consequently that it follows the general law, the equation of which for this case is,

$$xz + bx + az = c \qquad C.$$

x and z being the two variables, mentioned above.

PLATE III.



CONDENSATION WITH VARIABLE AREAS EXPOSED.

Transposing, eliminating and substituting, as in the first application of the general formula, we find for the values of the constants,

$$a = -4{\cdot}77\,;\ b = -1{\cdot}026\,;\ c = 221{\cdot}36,$$

and these values substituted in equation *C*, gives

$$xz - 1{\cdot}026 \times -4{\cdot}77\,z = 221{\cdot}36 \qquad D.$$

By substituting the values of z, and calculating for x, we find when

$z = 13{\cdot}86$;	z = cylinder condensation = 22·01;	error of $-$ 0·39
12·21;	25·00;	$\pm$ 0·000
10·56;	28·50;	$\pm$ 0·000
8·91;	33·50;	$-$ 2·50
7·26;	41·06;	$-$ 2·94

This equation then satisfies the results obtained by experiment so closely, that it may be taken to represent this law of condensation as a function of the area exposed in square feet in this engine, to the action of the steam during the set of trials made for Case I. The equation is that of an hyperbola and may be written,

$$(x - 4{\cdot}77)\ (z - 1{\cdot}0266) = 216{\cdot}47 \qquad D.$$

or if $x' = x - 4{\cdot}77$, and $z' = z - 1{\cdot}026$

we have

$$x'\,z' = 216{\cdot}47$$

which is the equation of an hyperbola referred to its asymptotes.

23. COMPARISON WITH EXPERIMENT AND VERIFICATION OF FORM OF FUNCTION AND CONSTANT.

Substituting in equation A, which is,

$$x\,y + {\cdot}44\,x + {\cdot}12\,y = {\cdot}3,$$

the different values of y = fraction of stroke completed up to cut-off, we have shown how nearly the calculated results corresponded with those obtained by direct experiment as given by the abscisses of the curve of *Plate I*, thus proving within what limits the equation is correct, and at the same time affords means of comparison as given by other authors upon this subject.

Dr. R. H. Thurston, in his paper on the "Theory of the Steam Engine" (J.F.I., 1884), concludes from the experiments of Mr. Isherwood that cylinder condensation varies sensibly as the square root of the ratio of expansion and that the amount of such condensation usually lies between one-tenth and one-fifth of the square root of that ratio, if estimated as a fraction of the quantity of steam demanded by a similar engine having an unjacketed cylinder.

Therefore, substituting in the general formula,

$$x = a\sqrt{r}$$

in which,

$x =$ per cent. of condensation
and $r =$ ratio of expansion,

the values of a and r and solving for the former, we should obtain, according to Professor Thurston, values for a lying between one-fifth and one-tenth. Taking the values of *Plate I*, and substituting the values of r, when the cut-off is 0·15, we have for the ratio of expansion 6·6666 +, and for the per cent. of condensation 48·25, and these values in

$$a = \frac{x}{\sqrt{r}}$$

gives us

$$a = \frac{48{\cdot}25}{\sqrt{6{\cdot}6666}} = \frac{48{\cdot}25}{2.58} = {\cdot}187.$$

Substituting for cut-off at ¼ when $r = 4{\cdot}$, and solving, we have

$$a = {\cdot}1987 +$$

Substituting for cut-off at ·35 when $r = 2{\cdot}8571$, and solving, we have

$$a = {\cdot}1923 +$$

Substituting for cut-off at ·45 when $r = 2{\cdot}2222$ and solving, we have

$$a = {\cdot}1812$$

Substituting for cut-off at ·55 when $r = 1{\cdot}8182$ and solving, we have

$$a = {\cdot}174$$

Summarizing, we have

when $r = 6{\cdot}66$	+ ;	$a = 0{\cdot}187$
$r = 4{\cdot}00$	;	$a = 0{\cdot}1987$
$r = 2{\cdot}857$	;	$a = 0{\cdot}1923$
$r = 2{\cdot}222$	+ ;	$a = 0{\cdot}1812$
$r = 1{\cdot}82$	;	$a = 0{\cdot}174$

From which it will be seen that the values of a lie between one-tenth and one-fifth and are almost equal to one-fifth in nearly all the tests to which the equation was applied, showing that, as Professor Thurston predicted, several years ago, the amount of cylinder condensation lies between one-tenth and one-fifth of the square root of the ratio of expansion, and that the results of this case, with variable ratio of expansion, very nearly coincide with those of Mr. Isherwood.

CHAPTER V.

23. CALCULATION AND LAW OF CASE II.

In this case, as in the preceding, great care was taken to secure similar constant conditions in all the trials, and to maintain them as far as circumstances would permit. The logs containing the data of Case II will be found in Chapter III. Table 2 contains the data classified and the calculated results of the experiments made upon the engine used, to determine the effect of the boiler pressure upon condensation of steam in the steam engine cylinder. The experiments were five in number, though four of them only so fall within range as to permit of an expression being formed to represent the law of condensation.

The pressures used for the different trials are 80·0, 65·85, 52·33, 37·0 and 22·3; the real cut-off was taken at one-fifth, though the average is ·222, this being due to the third and fifth tests of this set, the others being nearly constant. The speed under which the tests were run, was kept as constant as the controlling mechanism permitted. The average is 69·6 revolutions, the greatest difference of any two of them is 3·6 revolutions, and the greatest difference between the average and the fastest speed amounts to 2·1 revolutions. The calculations for Case II were in all respects similar to those of Case I. Though the meter readings are given, the feed water consumed is calculated from the weir, this probably giving the more correct value.

24. GENERAL METHOD OF CALCULATION AND OF DEDUCTION OF LAW OF CONDENSATION, WITH VARYING RANGE OF PRESSURE.

In the annexed table, will be found the data and results as already mentioned in the last article.

(*See Table No.* 2.)

The experiments are five in number and are arranged under their respective boiler pressures of 80·0, 66·85, 52·33, 37·0 and 22·3 pounds to the square inch. This number was deemed sufficient to obtain an expression for cylinder condensation as a function of the boiler pressure. They are also within range of those used in every-day practice, especially in the type of engine used for our experiments. For facility of reference, the experiments are ranged in groups and the lines composing them numbered.

Case II.—Condensing.—Variable Boiler Pressure.

Table No. 2.—Containing the Data and Results of Experiments, made at Sandy Hook, Conn., to determine the Laws of Cylinder Condensation.

Number of Line.			Variable Steam Pressures of the Boilers.				
			80·0	66·85	52·33	37·0	22·3
1	Time.	Date of commencing experiment,	A. M. 8·07, May 26.	A. M. 10·38, May 26.	P. M. 2·54, May 26.	A. M. 7·36, May 27.	A. M. 10·15, May
2		Date of ending experiment,	A. M. 10·07, May 26.	P. M. 12·23, May 26.	P. M. 4·54, May 26.	A. M. 9·36, May 27.	P. M. 12·27, May 27.
3		Duration of experiment, in consecutive minutes,	120	105	120	120	120
4	Total Quantities.	Number of double strokes made by the engine piston, per counter,	8282	7426	8608	8270	8151
5		Number of pounds of feed water pumped into the boilers, per weir,	6413·5	6020·4	5505·2	3723·9	2875·2
6		Number of pounds of feed water pumped into the boilers, per weir per hour,	3206·75	3444·8	2752·6	1861·95	1437·6
7		Average height of water over weir, in inches, ♦	3·8691	3·4516	3·4154	3·0518	2·4642
8	Engine.	Number of double strokes made per minute by the engine piston,	69·016	70·72	71·73	68·91	67·925
9		Vacuum in condenser in inches of mercury, per gauge,	22·44	22·25	22·44	22·69	23·
10		Fraction of stroke of piston completed when steam was cut off (apparent),	·186	·184	·223	·188	·2209
11		Fraction of stroke of piston completed when steam was cut off (real),	·208	·206	·244	·2102	·242
12	STEAM PRESSURES In Cylinder per Indicator.	In pounds per square inch above zero, at cutting off the steam,	78·80	66·89	53·21	39·83	26·74
13		In pounds per square inch above zero, at release,	18 08	15·53	14·34	9·80	7·96
14		Mean gross effective pressure in pounds per square inch on piston during its stroke,	36·89	29·55	25·29	16 02	10·32
15		Pressure in pounds per square inch required to work the engine,	3·5	3·5	3·5	3·5	3·5
16		Mean net effective pressure in pounds per square inch on piston during its stroke,	33·39	26·05	21 79	12·52	6·82
17		Per cent. of which the mean net effective pressure is of the mean gross effective pressure,	90·43	88·15	86·16	78·15	66 09
18	POWER. Absolute.	Gross effective horses-power developed by the engine,	134·403	111·86	96·533	58·808	37·343
19		Net effective horses-power usefully applied,	121·542	98 604	83· 73	45·958	24·68
20	POWER. Economic.	Pounds of feed water consumed per hour per gross effective P.,	23·86	30·79	28·50	31·66	38·49
21		Pounds of feed water consumed per hour per net effective P.,	26 38	34 93	33·09	40·51	58·24
22	Temperature in Deg. Fahr.	Of the injection water,	66·	66·	68·	64 66	64·25
23		Of the water in the weir,	107·	118·87	111·55	99·88	101·6
24		Of the feed water,	87·	102·	114·	112·	106·
25		Per cent. of the amount of feed water that passed into the cylinder from the boilers, in the form of water entrained in the steam, due to incomplete evaporation,	8·86	9·18	7·00	7·35	8·37
26		Total pounds of steam in the cylinder at cut off, calculated from the pressure of the steam in the cylinder at the point of cut-off,	4153·34	3144·612	3476·82	2180·79	1690·848
27		Pounds of steam in the cylinder at cut-off; calculated from the pressure of the steam in the cylinder at the point of cut-off, at the end of one hour,	2076·67	1796·92	1738·42	1090 395	845·424
28		Total pounds of steam in the cylinder at release; calculated from the pressure of the steam in the cylinder, immediately before the opening of exhaust,	4604·858	3590·129	3860·15	2595·92	2103 209
29		Total number of thermal units in the steam, expended by the engine as calculated from the feed water,	6580861 87	6078084·2	5673358·6	3846859·43	2916473·8
30		Total number of thermal units, as per weir,	5557807·5	5286598 9	4908042·3	3302025·9	2586046·9
31		Per cent. of the steam evaporated in the boilers, not accounted for by the indicator, at cut-off,	35·24	47·83	36 84	41·43	41·19
32		Temperature corresponding to the boiler pressure,	323·657	313·134	299·815	282·954	262·451
33		Temperature corresponding to the back pressure,	160·663	164·953	164·253	162·330	160 941
34		Range of temperature worked through, as per card,	162·994	148·881	135 562	120·624	101·510
35		Range of pressure worked through, as per card,	89·88	76·30	61·78	46·7	32·15

Time.—Lines 1 to 3 contain the time of commencing and ending experiment and of duration in consecutive minutes. As the contents of the lines in each of the groups of Table 1 have been clearly stated, and the manner of obtaining the results, where there may have existed any seeming obscurity, clearly outlined by formulæ and direct applications, it is not deemed necessary here to repeat the statements regarding each line and group; but those only will be explained that have been added to the groups. The numbers of the lines of Table 2, do not follow those of Table 1; but are similarly worded, so that reference can easily be made by referring to the groups in each of the cases.

Engine.—Line 10 contains the fraction of the apparent stroke completed when the steam was cut off; this is the ratio which the length of the stroke up to the point of cutting off the steam is, of the total length of the cylinder.

Line 11 contains the fraction of the (real) stroke completed when the steam was cut off, and is the ratio which the length of stroke to the point of cut-off plus that due to clearance, is of the total length of the cylinder plus that due to clearance.

Line 32 contains the temperatures corresponding to that of the steam in the boilers. It is obtained by interpolating in Porter's tables.

Line 33 contains the temperature corresponding to the back pressure on the piston as taken from the indicator diagrams.

Line 34 contains the range of temperature worked through as per card, and is the difference between the quantities on lines 32 and 33.

Line 35 contains the range of pressure worked through as per card, and is obtained by taking the difference between the heights of the admission line of the indicator card and the back pressure line, both calculated from a common zero multiplied by the scale of the spring used in the trial.

25. CALCULATIONS IN DETAIL—RESULTS DISCUSSED AND CLASSIFIED—FINAL EXPRESSIONS AND CURVES REPRESENTING THEM.

The variation of the conditions intended to have been kept constant in this trial have already been alluded to. Though these variations are a trifle greater than those of the first case and as the corrections for condensation with varying ratios of expansion can

not well be applied; the results are taken as put down in Table 2, we thus have, for a

Pressure of 80· pounds;	a condensation of 35·24 per cent.
66·85	47·83
52·33	36·84
37·0	41·43
22·3	41·19

from which we see that the condensation changes slowly with changes of pressure and temperature.

Thus in a variation of pressure of nearly sixty pounds the per cent. of condensation and (excepting one case) varies but six per cent. As already stated, some error must have been made in the observation of the second trial of May 26th, and that the final result will not be taken into account.

Plotting the results of Table 2 on paper, upon which the abscisses represent the per cent. of condensation and the ordinates the pressures in the boilers, we find that the intersections are nearly in line; so that if it were attempted to pass a curve through these four points, it would be very irregular and could not be algebraically expressed.

26. METHOD OF DEDUCING ALGEBRAIC EXPRESSION FOR VARIATION OF CONDENSATION IN CASE II, AS A FUNCTION OF THE BOILER PRESSURE.

The results of the trials of Case II, cannot be applied to the finding of an expression representing the law of condensation for this case, as the values given by the right line of *Plate IV* do not correspond with the calculated results.

Let $(x' y')$ and $(x'' y'')$ be the two points through which the right line

$$x = my + b$$

is made to pass. The coördinates of the point must satisfy the equation to the line; hence, we have the two equations of condition,

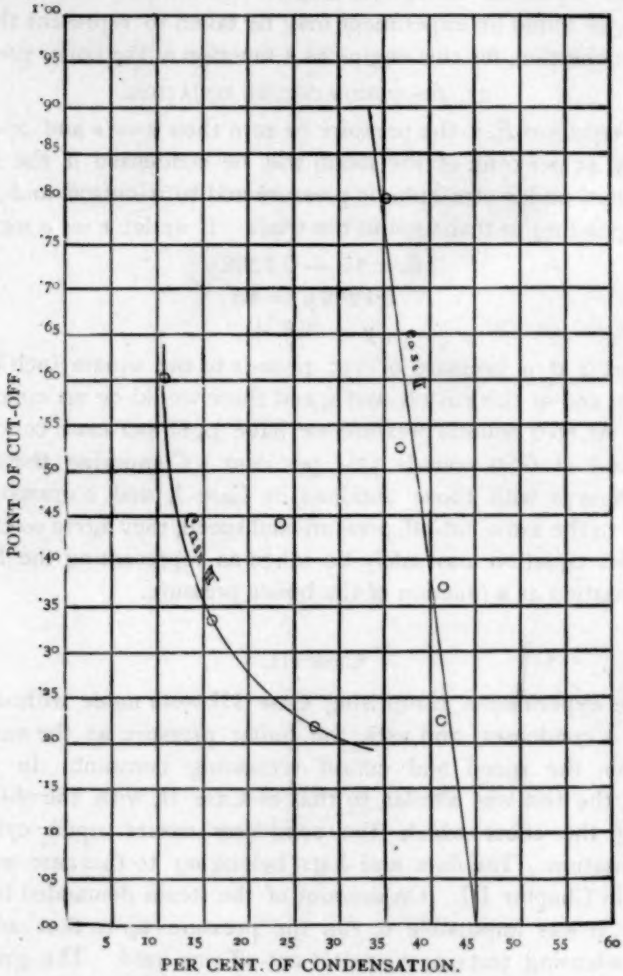
$$x' = my' + b$$
$$x'' = my'' + b$$

Taking the values of $(x' y')$ and $(x'' y'')$ from *Plate IV*, substituting them in the equations of conditions, and eliminating, we obtain, for the value of the constants $b = 45$ and $m = -0.1266+$.

Substituting these in the ordinary equation to the right line, we have

$$x = 45 - 0{\cdot}1266\, y \qquad E.$$

PLATE IV.



CONDENSATION WITH VARYING PRESSURE.

This equation representing the law of cylinder condensation for this engine, as a function of the boiler pressure, we will now test; by substituting $y = 80{\cdot}0$, $52{\cdot}33$, $37{\cdot}0$ and $22{\cdot}3$, and compute the values for x, we thus find,

y = pressure = $80{\cdot}0$;	x = cylinder condensation = $34{\cdot}88$;	error of—	·036
= $52{\cdot}33$;	= $38{\cdot}38$;	+	1·54
= $37{\cdot}0$;	= $40{\cdot}32$;	—	1·11
= $22{\cdot}3$;	= $42{\cdot}27$;	+	1·08

This equation, though it does not absolutely represent the values as found by experiment may be taken to represent the law of condensation, for this engine as a function of the boiler pressure.

27. DISCUSSION OF THE EQUATION.

In equation *E*, if the pressure be zero then $y = o$ and $x = 45$; that is, 45 per cent. of the steam will be condensed if the steam were used under atmospheric pressure and to a cut-off and speed corresponding to that used in the trials. If we let $x = o$ we have,

$$o = 45 - 0{\cdot}1266\,y$$
$$0{\cdot}1266\,y = 45$$
$$y = 355 +.$$

That is at a pressure of 355 pounds to the square inch in the boilers, and at this cut-off and speed there would be no condensation. At 80·0 pounds pressure we have 34·88 per cent. condensation, and at 60·0 pounds 37·4 per cent. Comparing these two latter figures with those obtained in Case I, and corresponding nearly to the same cut-off, pressure and speed, they agree so closely that this equation may safely be taken as representing the law of condensation as a function of the boiler pressure.

CASE III.

The experiments comprising Case III were made without the use of a condenser, and with the boiler pressure as the variable function, the speed and cut-off remaining constant. In other words, the test was similar to that of Case II, with the object of finding the effect which the condenser exerts upon cylinder condensation. The data and logs belonging to this case will be found in Chapter III. On account of the steam demanded by the engine, it was impossible to run the pressure up to that used in the condensing tests, as a greater cut-off was used. The greatest average pressure obtained in this set was that of the first trial, on May 28th, when the fires were at their best, the average pressure being 60·15 pounds; trials were also made at 44·09, 33·5 and 21·69 pounds to the square inch.

The real cut-offs under which the tests were run corresponded to nearly ·41, the apparent ratio of expansion, therefore, being about 2½.

(*See Table No. 3.*)

Case III.—Non-Condensing.—Variable Boiler Pressure.

Table No. 3.—Containing the Data and Results of the Experiments made at Sandy Hook, Conn., to determine the Law of Cylinder Condensation.

Number of Line.			Variable Steam Pressures of the Boilers.			
			60·15	44·09	33·5	21·69
1	Time.	Date of commencing experiment,	A. M. 7 30 May 28.	A. M. 11 08, May 28.	P. M. 2·19, May 28.	P. M. 1·50, May 27.
2		Date of ending experiment	A. M. 10·30, May 28.	P. M. 1·38, May 28.	P. M. 5·19, May 29.	P. M. 4·50, May 27.
3		Duration of experiment in consecutive minutes,	180	150	180	180
4	Total Quantities	Number of double strokes made by the engine piston, per counter,	12237	10286	12153	11973
5		Number of pounds of feed water pumped into boilers, per meter,	11218	8421.	7332·42	5540 43
6		Number of pounds of feed water pumped into boilers, per hour,	3739·33	3368·4	2444·14	1846·81
7	Engine.	Number of double strokes made per minute by the engine piston,	67·98	68·57	67 51	66·52
8		Fraction of the stroke of piston completed when steam was cut off (apparent)	·3955	·4034	·384	451
9		Fraction of the stroke of piston completed when steam was cut off (real)	·4121	·4198	·401	466
10	STEAM PRESSURES In Cylinder per Indicator	In pounds per square inch above atmosphere in boilers, per gauge,	60 15	44·09	33·5	21·69
11		In pounds per square inch above zero at cutting off the steam,	65 36	5·.42	4 52	28 40
12		In pounds per square inch above zero at release,	27 66	22·28	18·02	14 25
13		In pounds per square inch above zero against the piston during its stroke,	14·7	14 82	14 88	14·84
14		Mean gross effective pressure in pounds per square inch on piston during its stroke	34 87	23 85	15 84	8·04
15		Pressure in pounds per square inch required to work the engine,	3 5	3 5	3 5	3 5
16		Mean net effective pressure in pounds per square inch on piston during its stroke,	31 37	20 35	12·34	4 54
17		Per cent of which the mean net effective pressure is of the mean gross effective pressure,	89 96	85 32	77·90	56·45
18	POWER. Absolute.	Gross effective horses-power, developed by the engine,	126 301	87·23	57 05	28 315
19		Net horses-power, usefully applied,	113 80	74·424	44 442	16 096
20	Economic.	Pounds of feed water consumed per hour per gross effective P.,	29·56	38·62	42 84	64 75
21		Pounds of feed water consumed per hour per net effective P.,	32 85	45·26	54·99	114·80
22	Temperature in Deg. Fahr.	Of the feed water,	112·77	95·4	98 903	104·11
23		Of the steam corresponding to the pressure in the boilers,	307 251	291 192	278·549	261·461
24		Of the steam corresponding to the back pressure on the card,	212·00	212·401	212·609	212 471
25		Of the range worked through, as per card,	95·251	78·791	65·940	48·990
26		Per cent. of the amount of feed water, that passed into the cylinder from the boilers, in the form of water entrained in the steam, due to incomplete evaporation,	8·15	7·44	10·23	8 7
27		Pounds of steam in the cylinder at cut-off, calculated from the pressure of the steam in the cylinder at cut-off, at the end of one hour,	3333·69	2576 32	2055·07	1341·88
28		Pounds of steam in the cylinder at release, calculated from the pressure of the steam in the cylinder immediately before the opening of exhaust, at the end of one hour,	3439·65	2819·72	2241·48	1848·16
29		Number of thermal units in the steam expended by the engine, calculated from the feed water consumed,	12726945·1	9558675·1	8102018 9	6165009.6
30		Number of thermal units in the steam expended by the engine, calculated from the feed water consumed, at the end of one hour,	4242315·	3823470·	2700672·	2055003·2
31		Thermal units per hour, equivalent to the gross effective horse-power,	324437·	223719·	146316.	73133·
32		Per cent. of the steam evaporated in the boilers not accounted for by the indicator at cut-off,	10·85	23 51	15 92	27·34

The quantities are summarized and placed under their respective headings, as in the previous tables. The lines are numbered, and the first twenty-five correspond, with one exception, to those of Case II. It will therefore not be necessary to review these again.

Line 29 contains the thermal units, as calculated from the amount of feed water pumped into the boilers and delivered to the engine. The heat units in a pound of steam and water were taken from Porter's tables. The product of the heat units in one pound of a mixture of steam and water into the whole number of pounds delivered to the engine gives the quantity on line 29.

Line 30 contains the thermal units expended by the engine in one hour, and is found by dividing the quantity on line 27 by the duration of the test in hours.

From Table 3, we see that the per cent. of condensation corresponding to 44·09 pounds pressure is probably too high, as compared with the others. As there are only four trials in this case, and as a curve cannot well be traced through the plotted results, as shown on *Plate IV*, the curve was passed only through three points.

Further calculation and discussion is not deemed necessary, as the curve representing any one of the conic sections could be passed through these three points. It can, however, be seen that the curve has a similar direction to that of Case I, and that the tendency of it is asymptotic, as in the first case.

CHAPTER VI.

28. CALCULATIONS AND LAW OF CASE IV.

Tests 14, 15 and 16 of Case IV were the last trials made, and were for the object of finding the effect of speed or varying time of exposure upon the amount of condensation in the steam engine cylinder, the constant conditions being boiler-pressure and ratio of expansion. From the logs and Table 4, we see that the conditions have been kept about at the same point during the three trials. It is unfortunate that a fourth one was not obtained, but the engine after that time was used to furnish the power for the mill. A fourth point would have definitely settled which direction the curve would have taken. As the three points found are, however, so nearly in line when plotted, we will consider the equation to be that of a straight line, and base the law thereupon accordingly. The revolutions are 62·977, 50·3 and 33·74, corresponding respectively to the 16th, 15th and 14th tests, of which the logs are given in Chapter III. Steam was permitted to follow full stroke and the real cut-off corresponded nearly to the opening of the exhaust and was for the apparent ·9367, ·9604 and ·9803 of the stroke of the engine, and for the real cut-off, ·9384, ·9614 and ·9809.

The boiler pressure was kept as nearly constant as possible, the average pressure being 19·25. The greatest variation being ·32 of a pound from the average, an amount which cannot in any way affect the results of the per cent. of condensation obtained.

29. GENERAL METHOD FOR CASE OF VARYING TIME OF EXPOSURE AND SPEED OF ENGINE.

In the annexed table, will be found the observed data and the calculated results of the experiments made for the purpose of determining the law of cylinder condensation as a function of the speed of the engine.

(*See Table No. 4.*)

The experiments are three in number, and the results are arranged in parallel columns under the respective speeds of 62 977, 50·3 and 33·74 revolutions per minute. The engine could not well be run lower than thirty-three revolutions, though had it been possible to supply more steam, a higher speed might have been obtained.

The quantities, for facility of reference, are arranged as far as

Case IV.—Condensing.—Variable Revolutions.

Table No. 4.—Containing the Data and Results of the Experiments, made at Sandy Hook, Conn., to determine the Laws of Cylinder Condensation.

Number of Line.				Variable Revolutions.		
				62·977	50·3	33 74
1		Time.	Date of commencing the experiment,	P. M. 3·00, May 29.	A. M. 9 47, May 29.	A. M. 7·57, May 29.
2			Date of ending experiment,	P. M. 4.30, May 29.	A. M 11·47, May 29.	A. M. 9·42, May 29.
3			Duration of experiment in consecutive minutes,	90	120	105
4		Total Quantities.	Number of double strokes made by the engine piston, per counter,	5668	6036	3543
5			Number of pounds of feed water pumped into boilers, per weir,	6173·75	7331 6	4731·82
6			Number of pounds of feed water pumped into boilers, per weir per hour,	4115·83	3665·8	2703·897
7			Average height of water over weir, in inches,	4·1434	2·9671	2·2505
8		Engine.	Number of double strokes made per minute by the engine piston,	62·977	50·3	33·74
9			Vacuum in condenser, in inches of mercury. per gauge,	23·625	22·208	20·
10			Fraction of the stroke of piston completed when the steam was cut off (apparen).	·9367	·9604	·9803
11			Fraction of the stroke of piston completed when the steam was cut off (real),	·9384	·9614	·9809
12	STEAM PRESSURES	In Cylinder per Indicator.	In pounds per square inch above atmosphere in boilers, per gauge,	19·05	19·04	19·67
13			In pounds per square inch above zero, at cutting off the steam,	27·38	28·35	28·53
14			In pounds per square inch above zero, at release,	25·71	27·91	28·53
15			Mean gross effective pressure in pounds per square inch on piston during its stroke,	21·61	22·26	22·04
16			Pressure in pounds on the square inch required to work the engine,	3·5	3·5	3·5
17			Mean net effective pressure in pounds per square inch on piston during its stroke,	18·11	18·76	18·54
18			Per cent. of which the mean net effective pressure is of the mean gross effective pressure,	83·80	84·28	84 12
19	POWER.	Absolute.	Gross effective horses-power developed by the engine,	72·64	59·76	39·69
20			Net effective horses-power usefully applied,	60·87	50·37	33·39
21		Economic.	Pounds of feed water consumed per hour, per gross effective horses-power,	56·66	61·34	68·12
22			Pounds of feed water consumed per hour, per net effective horses-power,	67·61	72·77	80 98
23	Temperature in Deg. Fahr.		Of the injection water,	54·1	52·54	52·5
24			Of the water in the weir,	105·3	124·5	132·42
25			Of the feed water,	98·2	92 5	114·
26			Per cent. of the amount of feed water that passed into the cylinder from the boilers, in the form of water entrained in the steam, due to incomplete evaporation,	5·81	9·23	9·66
27			Total pounds of steam in the cylinder at cut-off, calculated from the pressure of the steam in the cylinder at the point of cut-off,	4669·038	5233·303	3146·367
28			Pounds of steam in the cylinder at cut-off calculated from the pressure of the steam in the cylinder at the point of cut-off at the end of one hour,	3112·7	2611·65	1797·92
29			Pounds of steam in the cylinder at release, calculated from the pressure of the steam in the cylinder, immediately before the opening of exhaust,	4669·058	5238·002	3146·367
30			Total number of thermal units in the steam, expended by the engine, calculated from the feed water consumed,	6375554·4	7195805·61	4589394·75
31			Total number of thermal units, as per weir,	5792506 9	6546615·3	4192714·5
32			Per cent. of the steam evaporated in the boilers, not accounted for by the indicator at cut-off,	24·37	28·75	33·506

practicable in groups and their lines numbered. The lines, their contents and any new data added have previously received mention, that it is not necessary here to again allude to them separately.

30. CALCULATIONS IN DETAIL—RESULTS DISCUSSED AND CLASSIFIED—FINAL EXPRESSIONS AND CURVES REPRESENTING THEM.

In examining Table 4, it will be seen that the conditions under which the trials were run, were so strictly adhered to, and the results obtained varied so slightly, that an expression from these results determining the per cent. of condensation as a function of the speed, may be taken as strictly representing the losses occurring by condensation in this engine. The greatest variation in the range of pressure for the three tests was three and one-half per cent., a quantity seemingly large, but in reality very small when the low pressure is considered. The greatest variation in the cut-off is not sufficiently large to affect in the slightest degree the per cent. of condensation, as the greatest fluctuation from the lowest to the highest cut-off used amounts to but $\frac{4}{100}$th, which is one-half of one per cent., and but one-fifth of one of the average cut-off.

The per cent. of condensation is given in line 32, from which we have:

Revolutions per minute,	62·977;	per cent. of condensation,	24·37
	50·3		28·75
	33·74		33·506

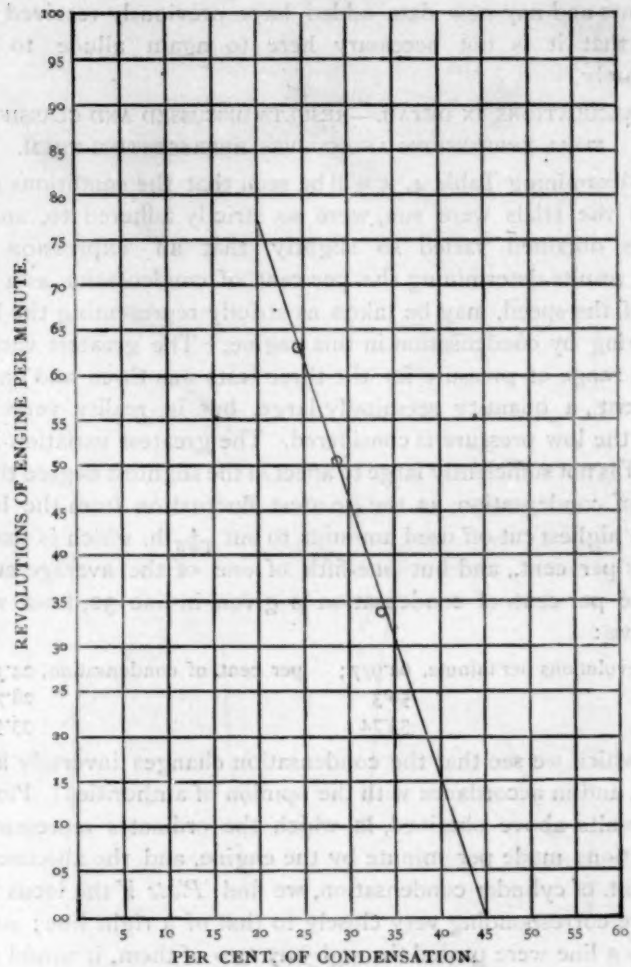
from which we see that the condensation changes inversely as the speed, and in accordance with the opinion of authorities. Plotting the results above obtained, in which the ordinates represent the revolutions made per minute by the engine, and the abscisses the per cent. of cylinder condensation, we find *Plate V* the locus to be a curve corresponding very closely to that of a right line; so that if such a line were passed through any two of them, it would differ but very little from the result as found by experiment.

31. METHOD OF DEDUCING ALGEBRAIC EXPRESSIONS FOR VARIATION OF CONDENSATION IN CASE IV.

Applying the equations to a right line, as in Case II, we find for the value of the constants m and b,

$$m = -0{\cdot}33$$
$$b = 45{\cdot}$$

PLATE V.



CONDENSATION WITH ENGINE-SPEED VARIABLE.

and substituting these values of m and b in the equations,

$$x = my + b,$$

we have

$$x = -45 \cdot 0{\cdot}33\, y \qquad F.$$

We now test equation F, by substituting $y = 62{\cdot}977$, $50{\cdot}3$ and $33{\cdot}74$ and computing the values for x, we thus find

y = Revolutions per min. =	62·977;	x = Cyl. Con. =	24·22; error — 0·15
	50·3		28·41 = 0·34
	33·74		33·86 +0·504

This equation then satisfies so closely the results obtained by direct observation, that it may be taken to represent the law of condensation as a function of the varying time of exposure for this engine.

Discussion of the equation. In equation F, if the speed be zero, $y = o$, and the condensation, under the conditions of the tests, will be forty-five per cent. of the steam introduced into the cylinder.

If the condensation be zero, $x = o$, and $y = 140$ nearly, or at a speed of 140 revolutions, there would be no condensation.

These latter results are, however, of small consequence, as they result from extending an empirical formula, too far beyond the limits of the experiments, in both directions, upon which it is founded.

Erratum.—In Chapter I, § 4, after "incomplete and unsatisfactory," *read:* "for some of the purposes of this investigation."

Spectrum of Ozone.—Besides the eleven bands observed by Chappuis, E. Schoene has detected one more at wave-length 516, and another, still somewhat doubtful, at about 452. The quantity of ozone in a gas may be determined with the spectroscope, since for a source of light of given intensity, the increase in the amount of ozone is accompanied by the successive appearance of the absorption-bands, the principal band (between 595 and 613) appearing first, the rest following in the order of their intensity. Schoene examined the spectrum of the atmosphere for some time daily before sunrise, and after sunset when the rays passed through a thick layer of air, the remarkable crepuscular phenomena observed throughout the whole of the globe at the end of 1883 having proved highly favorable to these investigations. Although the band of water (599—610, in the liquid, not in the solid state) coincides partly with the main band of ozone, observations made in intense frost, and the sky being entirely bright, leave scarcely any doubt whatever as to the presence of ozone in the atmosphere. The bands are not distinctly seen when the spectroscope is directed towards the sun itself. The so-called rain-band (partly coinciding with the main ozone-band, and extending to line D) also interferes with this kind of observation. This became so intense in spring that it was difficult to detect the presence of ozone in the air. This is the probable reason why in climates more warm and damp than that of Central Russia, the ozone-band could not be observed in the absorption-spectrum of the atmosphere.—*Jour. Chem. Soc., July, 1885.*

SCIENTIFIC METHOD IN MECHANICAL ENGINEERING.

By Coleman Sellers, Professor of Mechanics, Franklin Institute.

[*An Introductory Lecture to the Course on Mechanics, delivered before the* Franklin Institute, *November 6, 1885.*]

A lecture introducing the course on mechanics should in the first place indicate the ground that will be covered by the lecturers who are to follow, and the reason for the selection of the subjects to be treated by them. Owing to the high character of the lectures for this year I find my duty a pleasing one. It is customary to divide the whole lecture course of the Franklin Institute into three groups, twelve lectures being devoted to Chemistry, and a like number each to Physics and to Mechanics. These lectures, for the greater part, will call attention to matters of importance and not be entirely in the direction of elementary instruction in either branch. Chemistry and Physics are of the utmost importance to all engaged in any industrial art, and in some cases the first plays perhaps the more important part, while Physics, or the study of the laws that govern matter at rest or in motion, is the foundation of applied mechanics. In the broad view taken of the benefit to be derived from the lectures in this hall, the course on applied mechanics, this year is made to serve the purpose of bringing to the notice of the public the results already accomplished in mechanics, through the medium of those who are the most familiar with their accomplishment. We are living in an age of rapid progress, and the discoveries of to-day may be eclipsed by those of to-morrow. America is adding many pages to the history of mechanics, but America will not receive her share of acknowledgment for work done, unless her sons take care to write the history and give to those who have done the work the credit that is their due. The high pressure steam engine was invented in America, here in this very city, yet who is there in England that does not claim the invention for Trevithick, of England. Mr. Coleman Sellers, Jr., who has had his attention directed to the inventions of Oliver Evans, the real inventor of the high pressure steam engine, and who has written on the subject, has been asked to speak of Oliver Evans' inventions that the world may know what an American

did in the early stages of some of the mechanic arts of to-day. At Watertown Arsenal, there is in operation a testing machine, believed to be the most accurate that has ever been constructed, and which is always crowded with work. Its invention involves many new and beautiful mechanical devices. Its inventor, Mr. A. H. Emery, of Stamford, Conn., has been asked to speak about it, and his lecture will be on "Testing Machines as Instruments of Precision."

Mr. Wilfred Lewis, of this city, for a long time engaged in the prosecution of certain investigations in regard to the efficiency of mechanical movements, is therefore in position to give us some very interesting and useful ideas in regard to the loss involved in mechanical powers. His daily work is in the direction of what will be the burden of my lecture to-night. Locomotives have been made in Philadelphia ever since 1830, when Col. Long began his first engine, which was tried on the Newcastle and Frenchtown Railroad in 1831. American locomotives made in Philadelphia are now finding market in all parts of the civilized globe, and so it is very fitting that the story of the growth of the locomotive should be told by some one who has made it a study. Mr. M. N. Forney, lately editor of the *Railroad Gazette*, has consented to come over from New York to lecture on the "Evolution of the Locomotive." Col. William Ludlow, Chief Engineer Water Department of Philadelphia, who is using his best endeavors to give us pure and wholesome water, will lecture on "Water Supplies of Cities."

Iron and coal make a large part of the wealth of the State of Pennsylvania, and the smoke of the thousands of iron furnaces would blacken the air but for the treasure of anthracite that comes from our mines, and the natural gas that is now flowing from the wells in the western part of the State. Mr. John Hartman, whose business it is to construct the machinery used in the process of smelting iron, will deliver one lecture on "The Smelting Furnace," which will interest and instruct in that direction. The flow of solids is a new name coined in quite recent times. Under great pressure, cold metals are made to flow and assume new shapes. Mr. Oberlin Smith, the President of the Ferracute Machine Company, of Bridgeton, N. J., who forces sheet metal into shapes for use, will tell us how sheet metal flows in the drawing process; that is, how it behaves when forced through dies and the like. We are now hoping for a substantial bridge over the Schuylkill River at Market Street, and will be all the

better for some talk on the "Elementary Problems of Bridge Construction," so Mr. James Christie, of the Pencoyd Iron Works, of Philadelphia, has been asked to speak on that subject. The manufacture of worsted goods is carried on to a vast extent in this city, and we scarce realize the extent of that industry in our midst. We are astonished when we are told that more than half of all the carpets made in the world, are woven in Philadelphia, and the carpet industry is but a part of the textile industry of this place. Mr. T. C Search, who takes a most active interest in the school that is now being established in the interest of the textile trades, will give us the technology of worsted manufacture. As an accompaniment to what Col. Ludlow will say as to the water supply of cities, Mr. Rudolph Herring, the eminent hydraulic engineer, will lecture on "Sanitary Plumbing."

In a former lecture of mine, introducing the mechanical course of lectures, I said that in this city "a well-grounded knowledge of the great law or principle of conservation of energy should be taught with the multiplication table. It can be so taught if the teachers themselves are certain that there is in the universe only so much energy, and that we cannot make one particle more than already exists." We are to have one lecture on this subject from Prof. J E. Denton, of the Stevens Institute of Technology, Hoboken, N. J., who will give practical examples of this law of the conservation of energy. Last, but not least, Prof. De Volson Wood, of the same Institute, has promised to lecture, but illness has prevented him from stating his subject; that it will interest and instruct, there can be no doubt. Here, then, in connection with the admirable lectures that are given in the programme under the head of Chemistry and Physics, is presented a course that should crowd this hall.

Outside of what the FRANKLIN INSTITUTE is doing in the way of education through its lectures, its drawing-school, and its more difficult mode of instruction, but even more effective, its exhibitions of novelties in the mechanic arts, this year, is memorable as the one in which manual training has found a beginning in the curriculum of the public schools of the city. It is to be expected that zeal in this new movement, growing out of the interest the students will take in their work and the good fruit it will bear in quickening their perceptive faculties, will encourage the managers of the schools to widen the scope of this kind of tuition.

Manual training will, too, it is hoped, show the need of other lessons in the regular course—lessons bearing on the more extended knowledge of the principles that underlie mechanics. I propose, this evening, saying a few words to you on the part that systematic, scientific method should play in the most ordinary mechanical occupations, and to point out the need of orderly method in the advancement of all the arts. I had occasion, the other day, to watch the operation of a mechanical shoemaker, at work in the Novelties Exhibition. Boots and shoes were being sewed on this machine, the stitches made with brass wire; brass staples were selected, automatically, of the proper length, and were inserted in place. My attention had been critically drawn to this machine in acting as judge in the class to which it belonged; not very far away were books, which, in binding, were sewed with wire staples, and between the two were many devices to enable hand-sewing with wire staples to be done with ease. My mind naturally grouped these objects and processes, and even flew back over many, many years to days of childhood, when I had learned one of my first lessons in mechanics from my father, who held me in his arms, so small was I, as he showed me the then great wonder of fine steel wire bent in a machine into staples and driven through thick leather in rapid succession, to form the fine teeth of the cards used in carding wool and cotton fibre. I was not at, say, five years old, too young to remember the lesson when it was facts that were given me to think over. He took good care to point out that the fine wire forming the staple could be driven through the leather with precision, and without any holes having been pierced for it by more rigid needles, or through holes no larger than the wire forming the staples. The card clothing machines at Cardington were driven by water-power, but this mechanical shoemaker at the Novelties was driven by a steam engine of the highest type. That steam engine had its lesson to teach; a life, too, could span much of the period of transition from the first crude machines that grew out of Oliver Evans' notion of a high-pressure engine to the work of Corliss and others of to-day. It had made but little advance, even as early as I can remember, as compared to the results of to-day, and its slow growth had been after the manner of the survival of the fittest. Its history is cumbered with a vast amount of negative information, by years of mistakes, the result of empirical methods as against the systematic mode of more modern

research. As the steam engine grew towards its present state of perfection, in spite of the many drawbacks, the theory of thermo-dynamics took shape. The practical mechanic, who prides himself on the grand fact that he has drawn all his information, as it were, through the handle of the hammer he has worked with, has a holy horror of all that savors of science, and, what is more, he holds in contempt the scientific engineer. It was one of these practical men who presented a contrivance of his to a railroad company for trial; some of the directors thought it would be well to investigate, and the trial was made. The inventor, after said, that the failure was due to the scientific experts who conducted the trial. He suspected they had put some thermo-dynamics or some other scientific stuff into the boiler, on purpose to prevent his device from operating. Now, thermo-dynamics is the name given to the science that takes into consideration the corelation between heat and work. The designers of the great engines of to-day have the advantage of a pretty thorough knowledge of the laws that have been found to govern the conversion of heat into motion and of motion into heat. Could a knowledge of thermo-dynamics have preceded the steam engine, there is no telling how much farther we would have been now in our motive power department of the world's industries.

We are living in an age when the Baconian inductive system of research is relied on; the rapid progress of modern time is due to the results of the inductive system. In old times, the philosophers contrived theories to account for known facts. Lord Bacon was the one who clearly pointed out the need of obtaining many facts and finding the laws that govern matter through and by the study of the facts, but going beyond the range of the facts that we can obtain for the purpose of investigation.

The old philosopher stood on a hill and saw the land spread out before him as a mighty plain, and as he watched the movements of the heavenly bodies, he saw them rise in the East and sink below the horizon in the West. Upon this visible fact, he concluded with the more modern colored preacher in Virginia, that "the sun do move," because he saw it move and so from this visible fact he proceeded to build up a theory of astronomy and hunted for other facts to sustain his theory.

A more modern inductive philosopher, under the same condi-

tions perhaps, notices that objects floating on the surface of the sea sink out of sight at the horizon, and as these bodies are moving, hence infers that the surface of the world is round, and gathering many more facts, he then draws conclusions from his observation that enable him to look farther ahead and foretell, as it were, greater discoveries.

The wonderful progress of modern times is due wholly to the method that has been pursued of grouping facts in proper order, working out laws that govern matter, and proving that the laws are correct by finding no exception to them. An established law is what explains all phenomena bearing on it, and when no known fact offers any contradiction to it. Established laws are many, and the knowledge of these laws make the wisdom of the modern scientific mechanic. There are laws that can be so thoroughly trusted, that we no longer need investigate, and we follow them with confidence, knowing that we cannot change them, if we would do so. Gradually the knowledge of the world has become formulated, and we have in simple form ready for work the accumulated knowledge of all who have preceded us. We have before us, it is true, a vast field of experimental research, but we are in the position to guide our work systematically by the lights we now have. The day for empiricism in mechanics has gone by and I wish to show you this with a few simple illustrations.

I have here a ball, attached to the end of a piece of string, the string seems strong enough to carry the ball; at least, it does not break under the strain. I whirl the ball in a circle, and past experience leads me to infer that if I whirl it rapidly enough the string will break under a strain, due to the centrifugal force incident to the rotation. This fact is so well known to all of you, that it is not needful for me to prove it by trial. We hear of fly-wheels and grindstones breaking when revolved too rapidly. If, for any reason, I should desire to keep up the rotation of the ball at the end of the string with safety, I must know the force exerted on the string during rotation, and I must know the ultimate strength of the string. I have only to know the weight of the ball and its velocity in feet per second during rotation, and calculation will give me the strain on the string more accurately than I could obtain it by experiment. Now, on the other hand, no amount of calculation will tell me if this particular string is strong enough to

bear the strain with safety. To find out the ultimate, or breaking strength of the string, I must load it with an increasing weight until rupture takes place, and the information thus obtained can be used with some degree of certainty with the balance of the twine on the ball from which this was taken, or can be used to predicate the strength of another string of similar size and construction. This homely illustration will convey to your minds what I want to make clear, namely, just where we can rely on calculation, and where experiment must be resorted to continually. Let me now give you an example of the working of the scientific method in actual practice, covering a case involving calculations and experiment. Steam boilers have been made to serve the purpose of death traps from the most culpable neglect of ordinary precautions for safety, coupled with gross ignorance of Nature's laws, until the authorities were obliged to step in and define by laws certain precautions that must be taken for the welfare of the community. Steam boilers are made of sheets of iron or steel bent into shape and joined by rivets. As the strength of the entire structure is limited to the strength of the weakest individual part of the structure, it is of moment that the true value of any particular kind of riveted seam be known by actual experiment. There is no way of making the riveted seam as strong as the body of the metal. It is now usual, to so proportion the number and size of the rivets to the thickness of the plates to be joined, that the metal remaining between the rivet holes, shall about equal the strength of the rivets that unite them. In determining the pressure of steam a boiler already made can be permitted to work under, a calculation is gone into as to the strength of the seam, as measured by the area in section of metal between the rivets, and also measured by the size and number of the rivets, and the strength of the seam is assumed to be the lowest result of the calculation. After this, it may be necessary to know the strength of metal that forms the boiler, and just here is where the lesson of the ball and the string comes into play, and our present illustration is as readily understood. It does not require a very high order of talent to master the calculations that are resorted to, to determine what strain will come on this or that part of the boiler, and we have to rely wholly on calculation, for that information. The boiler must be made much stronger than

its ultimate or breaking strength of the metal to insure its safety in use, and to allow for deterioration. The difference between the ultimate or breaking strength and the strain that it is to be subjected to in practice, is regulated by what is termed the factor of safety. All well-considered specifications for structural metal work, for instance, call for the material to come up to some established standard of ultimate or breaking strength, and the amount of metal to be used in the structure is determined by a factor of safety specified. This factor of safety may be as low as four in some cases of boiler and bridge construction when the known character of the material used warrants the course, or it may be as high as thirty, in the case of matter subjected to shock or blows, as in the case of rapidly-revolving gear wheels. That is to say, it may be considered safe to strain the structure to one-fourth of what would cause it to break, or the case may require that we dare not strain it beyond one-thirtieth of its breaking strength. The question now presents itself, how can every sheet of iron or steel to be used in the construction of a boiler, for instance, be tested when such sheets are usually ordered from the mill of the exact size that is required, and to test a part of such sheet would destroy it for use. This furnishes me with a suitable example of the scientific method carried out whith ease and certainty in every-day practice.

Steam boilers of locomotives are worked at a rather high pressure, say 120 or 130 pounds to the square inch, and the metal now mostly used in their construction, is steel of a low grade as regards hardness, that is, steel of considerable ductility. From the specification for boiler and fire-box steel issued by the General Superintendent of Motive Power of the Pennsylvania Railroad, December 1, 1882, I extract the following :

(1.) A careful examination will be made of every sheet, and none will be received that show mechanical defects.

(2.) A test strip from each sheet, taken lengthwise of the sheet, and without annealing, should have a tensile strength of 55,000 pounds per square inch, and elongation of thirty per cent. in section originally two inches long.

(3.) Sheets will not be accepted if the test shows a tensile strength less than 50,000 pounds, or greater than 65,000 pounds per square inch, nor if the elongation falls below twenty-five per cent.

(4.) Should any sheets develop defects in working, they will be rejected.

(5.) Manufacturers must send one strip for each sheet (this strip must accompany the sheet in every case); both the sheet and strip being properly stamped with the marks designated by this company, and also lettered with white lead to facilitate matching.

Now let me explain this specification to you, as it has been explained to me in the admirable test room of the shops at Altoona :

There are many makers of steel boiler plate in the United States, and without referring by name to any one, I can state that the Pennsylvania Railroad has decided on a set of arbitrary signs to indicate each maker. One is designated by a triangular stamp, one other by a circular stamp that marks a ring of about one inch in diameter, another by a square of like size, and so on. Sheets of steel come from the rolls with a more or less irregular outline and of a size that will permit the tests strip to be cut off from one or the other edge without difficulty. The plate in the rough is, when cold, scribed to the required size of sheet that it is to be sheared to, and on the shear line two marks are made by the prescribed stamp, one mark being made at one blow of the hammer and the other by the same punch or stamp at another blow, and at any convenient distance from the other, but in no case are the two marks made by a twin set of punches or stamps at any fixed distance one from the other. This irregularity of the stamping renders the after matching of the strip, or coupon as it is called, an easy matter, with the sheet from which it has been cut, the shear cut being made directly through the marks. The matching is still further facilitated by numbers or signs in white lead.

After reception by the proper inspectors on the road, the samples, or coupons, are stamped with corresponding numbers after verification, and the test piece goes into the shop to be dressed to the proper width for the test, and the sample is then broken in a testing machine, and, in a book kept for that purpose, entry is made of every particular connected with the test, and the sheet received or rejected on this record. Suppose, however, that a sample shows a higher tensile strength than the maximum allowed, namely, 65,000 pounds per square inch, and that such specimen has an elongation or ductility as great as can be desired

it may be well asked why it should be rejected. In the book of record, I have seen some such cases, and reference is there made to the book of the chemist, into whose hands such sample is sure to go. His chemical test had in all cases, up to the time I saw the book, indicated too much carbon in the steel, and a simple physical test of heating and plunging the hot steel into cold water has shown it to be capable of being hardened. It is not deemed wise to employ any metal that has hardening qualities in the construction of steam boilers. After many such trials, the officers of the road have come to consider the tensile and ductility test as final, and as expressive of the qualities wanted. Thus, you see every sheet in every boiler has its physical quality when new recorded, and its marks enable its after history to be noted. No sheet of steel can meet with mishap afterwards, without having the report of the mishap recorded on the page that marked its acceptance, and its life or durability also noted. Such, in brief, is the account of the admirable scientific investigation into the quality of the material used in boilers, as reduced to practice, and so persistently pursued by this one company as to be now no longer a subject of comment. This method of test, however, is the outgrowth of systems that preceded it. Practice and theory must agree. The scientific engineer can lay claim to the title only when he is abundantly fortified by sound experience, and has learned to view all things evenly.

In the specification of the Pennsylvania Railroad, as already cited, stress is laid on the percentage of stretch before rupture takes place in the required test. The date of the printed specification I have referred to, is 1882. On January 8, 1881, I had a letter from the General Superintendent of Motive Power, in which he describes other tests which had been used for a long time. These were bending tests:

(1.) Bending cold.—A strip from each sheet must stand being bent over double, and being hammered down flat upon itself without fracture.

(2.) Bending after being heated and dipped.—A strip from each sheet must stand being bent over double, and being hammered down flat upon itself, after having been heated to a flanging heat and dipped into cold water, without sign of fracture.

He informed me that the bending tests had been insisted on for

several years, but that the certainty of the ductility test had caused them to make it the final mode of determining the quality of the steel submitted to them. In order to make the bending as uniform as possible, they adopted the plan of holding the strip to be bent between rigid jaws and striking the projecting end with a ten-pound sledge until it is deflected about 135°, when it was removed from the jaws and held with tongs while it was hammered down flat on an anvil. The bending after heating and dipping was added to protect them against acceptance of hard sheets, by reason of the test strips being annealed, accidently or otherwise by the manufacturers. He said that for some time past they had been testing tensilly, to obtain ultimate strength and ductility, a piece from the strip sent with each sheet, and had established a tensile test, which supplanted the bending test, but covered the same ground that it did. This was done on account of the greater regularity and uniformity of the results in tensile test, and because by it they obtain figures to show the exact quality of the steel; so that even in 1881 they were working under the specification I have already mentioned, as furnished me in 1882. Time is an important element in tests, particularly so in bending tests. An expert giving testimony in a trial in which the reliability of the steam engine indicator was in question, said, "I believe in the result of the use of the indicator when I know who works the instrument." The bending test is good, when you see it done in a proper manner, or know who does the bending.

Hurry the bending of good metal and it may break. Proceed with the bending of poor metal with caution, let it rest a bit between each blow, and a skilful man can bend a strip of brittle steel, so that the specimen will deceive the most expert. It is a very curious property of wrought iron and steel, that after being strained above the limit of elasticity and near to the point of fracture, rest will restore its strength. The story is told of some tests being made on beams for structural work before some officers of the Government. One maker strained a beam up to a point near to the breaking point and then invited the Board to test some champagne, saying that he was willing to let the beam remain, under its heavy load until after lunch. When the test was resumed, a strength was shown that could not have been reached had the rupture been hurried to completion and the metal had been allowed no time to accommodate itself to the strained condition.

Let me now go back to the consideration of material used in boilers. During the latter part of Mayor Stokley's administration, say about 1880, he, at the instance of the City Inspector of Steam Engines and Stationary Boilers, and of the officers of an insurance company for inspection and insurance of steam boilers, appointed a commission to devise some fixed rules, whereby uniformity of rating could be insured as to the pressure at which boilers may be worked. I had the honor of serving on that commission, and am thus enabled to tell you that we found a set of rules in force which gave to all boilers of the same diameter and the same thickness of metal the same pressure per square inch, regardless of the quality of the metal employed in construction and of the nature of the riveted seams. Fortunately, however, our City Inspectors of Steam Boilers were practical boiler-makers and were familiar with the requirements and could refuse to pass boilers manifestly unfit for use, for men long familiar with work of this kind come to learn what is right by experience and good common-sense. The ordinances passed by Councils, at the suggestion of the commission, made it imperative that all the conditions that exist in each boiler as to nature of seams, thickness and quality of the metal used, should be considered, and the boilers rated accordingly, giving the greater latitude to good workmanship and good quality of material combined with judicious proportioning of the parts. At the time to which I allude, but a few years ago, the United States laws in regard to the testing of boilers used in the marine service, called only for a knowledge of the tensile strength, and no notice was taken of the softness or ductility of the metal combined with great strength. I know a case in which a sheet had to be selected of higher tensile strength than could be obtained at the time, coupled with much ductility, to repair a boiler so that it would pass the Inspectors under United States laws. A lower ultimate tensile strength with high ductility would have made a safer job of the repair. We have come to the time now, when to hold our place in the world in competition with others, we should waste as little of our energies as possible in cutting and trying in any hap-hazard way and endeavor to avail ourselves of the acquired knowledge of the world generally, and make scientific application of the knowledge in our daily work.

We find it to our advantage to utilize the talent that comes

from the technical schools, only guiding and holding in check the schoolmen until they have learned the lesson of the workshop practice. You must bear in mind that it has been asserted that the *Puritan*, the *Genesta* and the *Pilgrim* were all designed by men who had a theoretical knowledge of boat building, and were not practical builders. The talent shown by the theorist who did save the cup for America in an international contest, might be utilized to advantage in the workshops of the practical boat-builder. On the other hand, the record of failures and mistakes for the want of practical experience, or sufficiently extended knowledge in the endeavors of newly-fledged scientific experts, are many and lamentable, as all know who are obliged to utilize their talents. Scientific men, too, have been charged, often wrongfully, with retarding progress. Dr. Lardner is accused of having stated, in his early lectures delivered in America, that the ocean could not be successfully navigated by steam, mainly on account of the large quantity of coal required, as compared with the carrying capacity of the vessel. It was in 1840 that he lectured here, and he remained in America until 1849. The *Sirius* and the *Great Western* steamships arrived in New York on St. George's day, April 23, 1838. Dr. Lardner's comments were made in England, at Bristol, August 25, 1837, before the Mechanical Section of the British Association. His opinion was asked, and was published in the *Times*, August 27, 1837. He never expressed a doubt as to the practicability as has been stated. The substance of what he then said was that the marine engine, with its then state of efficiency, was not able to cross the Atlantic from England to New York profitably without the patronage of Government. The engines of his day burned eight pounds or more of coal for every hourly horse-power developed, while we can do the same work with two pounds of coal per horse-power and we desire Government subsidy to keep our ships afloat.* Since the time that the *Great Western* steamed into New York harbor, what changes have been made in steam engines and in marine architecture. When in Scotland last year, I visited some of the noted ship-yards on the Clyde. In the yard of the Dennys, at Dunbarton, I was present at the trial of a model in the testing tank to determine the wave-line on the side of the ship. Certain side-wheel steamers were to

* See New York *Times*, January 8, 1881, letter of W. W. Evans.

be built, and it was advisable that the wave-line on the side of the ship, incident to the motion of the vessel, should be so fixed as to have the crest of a wave rise with certainty just where the paddle-wheel struck the water, and not compel the blade to reach down in the valley of the water for its hold in driving the ship forward. Theory had given a shape to produce this wave-line, and a model ship, about eight feet long, cast in paraffine, and worked up to the required lines on an expanse profiling or sculpturing machine was being tested and record made of all the conditions that could be noted by trained experts. In the same building, there were employed, I should think, at least twenty men and women, doing the clerical work of the calculations involved in scientific ship-building.

In London, last year, I was present in the lecture room of the Royal Institution, on Albemarle Street, in the room made celebrated by the exposition of the discoveries of Thomas Young, of Humphry Davy, of Michael Faraday, while each in turn presided over that Institution, and gave to the world, in that room, the result of their close scrutiny into the working of the laws that govern matter. The lecturer of the evening was treating of the motion of fluids, and one of his experiments was so striking that I venture to repeat it now, as it shows how much deeper we must go than the surface of what we see in search for exact truth. He produced a cubical block of wood, such as I now hold in my hand, suspended by a string attached to the centre of one of its faces. See, the block hangs like any other piece of inert matter, with its centre of gravity in line with the axis of the string. We see nothing unusual in the behavior of the block. If I try to make it hang in any other position, the force that placed in position being removed, it falls back to its normal position. If I attempt to make the block stand on one of its edges, it falls over, and we know, after a few trials, that such position is one of unstable equilibrium, and not to be relied on as permanent. I have here, however, a block, also of wood, of the same size and shape as the first one; it, too, is attached to a string; to all appearance, it is a similar block. I hold it in such a position that the string is dependent from one of the vertical faces of the block, and not from the upper one. I hold the string and release the block, and it does not fall from this constrained position, but seems to hang to one side of the

string, in what, to our senses, seems an abnormal position. I stand it on one edge, and it does not fall as did the first block. I might place it in other positions, and the effect would be as striking. Now, what makes one bit of wood act as we are accustomed to see matter act, and the other to act so differently? I will tell you: The first block was what it seemed to be, the second has motion inside of it, and that motion, under certain well-known laws, controlled the position of the block. See, I open the second block, which is hollow, and in the box is a brass top which has been and is yet spinning. The forces concerned in the rotation of the top were powerful enough to control the light form that simulated the block of wood.* The learned lecturer in London used this simple experiment to show what motion will do, and it was one of many experiments in the direction of showing the difficulties that attended the study of the motion of fluids, when motion within the fluid, not visible to the human eye, was exerting a controlling influence, and leading the mind of the observer away from the true facts of the case. I venture to show you this as illustrating the care that must be observed in seeking for truth. It requires a trained mind to follow the most direct road in any complicated investigation into the laws that govern matter, and the same training is needed by every mechanic in the orderly and systematic carrying out of his designs.

I have spoken of the inductive system of investigating the laws of the universe as practised now. Modern scientific advancement is measured by our knowledge of the laws that govern matter, and its progress is in proportion to the abandonment of empirical methods. All knowledge is based on the observation of facts, if we attempt to draw conclusions from too few facts, we may not be wrong in our conclusions when we have to deal with cases involving the same facts, but we may err greatly when our formulated method is carried in practice far beyond the experiments upon which it was based in the first case. I will mention a noticeable example: We are probably indebted to no one more than Morin

* The apparatus used consisted of two cubical blocks, each $6'' \times 6'' \times 6''$; one solid, the other formed of wood $\frac{3}{16}''$ thick, and in this box was a well-made gyroscope in a metal ring, loaned for the occasion by Messrs. Queen & Co., of this city. The attachment of the suspending cord was at the centre of the face of the block, close to one end of the axle of the gyroscope.

for his experiments on friction. No one has been able to controvert what he discovered in regard to the laws of friction, but cases occur in which there seems to be manifest disagreement with his laws, and these cases are always outside of the scope of his series of experiments. In other words, he did not carry his experiments far enough in the direction of velocity and in the direction of pressure, nor do we yet know all the conditions that obtain in the friction of different substances as we approach their destructive limit in use. As we extend our knowledge by still further experiments, we do not find any flaw in his expressed laws, so far as his light went, but we introduce other factors in the equation, factors that were of no moment in the experiments he tried, but which become the prime factors in the more severe requirements of application far beyond his in both directions. We are as yet, with all our information, but on the threshold of knowledge, but we are growing to be sure of one thing, that we have passed the time of empiricism, and to advance profitably we must pursue systematic rules of progress. In the competition of the world, we cannot afford to make mistakes; while to avoid mistakes, we must decide just what we want to do—the character of the material we have to use as well as the forces involved in the operation to be performed. We are to have a new bridge over the Schuylkill at Market Street some time. We are wise enough to know that it will not do to have that structure built by rule of thumb, trusting to rebuild it in a better manner later. It is doing things wrong once, twice and often many times before we stumble on what will barely serve our purpose, that is costing so much money and giving so little satisfaction and retarding progress. We cannot walk a square on any of our cobble-paved streets which should serve the purpose of facilitating the traffic over the road-bed, but we wonder at the want of knowledge shown by those who regulate our municipal matters and have permitted, and still permit, such structures to remain at a constant cost in detriment to the property hauled over them and the discomfort of ourselves. Street railways in many cases have their tracks perched on the centre of a narrow street with so much curve or camber to the pavement that the rail-bed is as high or higher than the curb-stones on either side, and the slanting pavement on either side of the track is on such an incline and so roughly paved with huge round stones, as to set at

defiance all the laws of mechanics, that dictate a road of the least resistance as the most economical, both in wear and tear to the road itself, but to the conveyances that pass over it. The locomotive proposed by Oliver Evans in the beginning of this century was to have run on the country roads, but he, with his limited knowledge, even hinted at special roads made to offer less resistance. Our streets are paved to make the most resistance. The locomotive was useless until it found a road adapted to its purpose. The success of the locomotive depended on the condition of the road it travelled on. Great results followed in practice when a scientifically-constructed and well-laid road was ready for the locomotive. Let us have smooth well laid streets, too.

Cable railroads have been in use in many cities for some years, their construction was experimental, and their present economy is problematical. I am not prepared to say just how scientifically they have been constructed in Chicago and the Far West, but here in our own city we are seeing a gigantic constructive experiment tried on the cut-and-try principle. Metallic conduits for the traction cable are put into place over miles of roads, the conduits being so formed as to have little or no power of resistance against the crush of the frozen ground, and even so made, as to present a shape most favorable to permitting the pavement to wedge the grip-slot shut. Wheels are put in to guide the ropes seemingly without any regard to strains that might have been known beforehand; or, if not known, should have been found out by careful experiment, and the citizens, who should be using the streets to their best profit and convenience, are kept off them by a constant succession of changes, involving tearing up, altering, replacing to the discomfort of our fellow-citizens, and to the loss of the company owning the road. The public are less interested if this cut-and-try system is taking place in the private workshops, and the public cares very little about the stages of progress through which any finished product has passed in reaching the stage of use to the consumer. The public are warranted, however, in objecting to unsystematic and ill-advised engineering enterprises being conducted to their detriment and delay. There will be no end, however, to just such empirical engineering. The desire to save in the first cost, without considering the after result of such false economy, will be the rule perhaps for a longer time in the

future than any one here is interested in, but it is the outgrowth of much evil in the methods of our schools. One of the first objects of education is, I think, to quicken the perception to teach the habit of observing phenomena clearly and quickly, to instil the desire to trace effects to their causes and to cultivate close and just reflection. The elements of geometry, physics and mechanics should have the preference over many of the traditional studies of the primary and the grammar schools, and what is more, the early introduction of such studies, presented to a child's mind in a practical form, as they can be, will prepare his mind for the more extended study of the higher branches of the same subjects in later years. As it is, the alphabet of science is not taught until the student is ready to read the subject in later life, when he should have grown up with a feeling that he always was in a measure familiar with the facts of the science.

General Francis A. Walker, President of the Massachusetts Institute of Technology, in a paper read before the American Social Science Association, September 9, 1884, said, in speaking on this subject: "Do you ask me how much of the elements of physics and mechanics should be given to a child of tender years? I answer, just as much as he will take, be the same more or less. And it is always safe to offer him more than he will take. It can't do him any harm. Cramming him with hard and lumpy facts, from so-called geographies or histories, may produce mental indigestion or colic; but an idea, an apprehended principle, never yet hurt a human being, and never will to the last syllable of recorded time. For myself, I would not stop teaching a child the doctrine of the persistance of force through all transmutations. Doubtless he would at first fail to apprehend it fully; yet he would gather something from it familiar, picturesque enunciation; and as the proposition became familiar to his ear, and as illustrations of the equivalency of motion, heat, light and sound were multiplied and repeated to him, I should hope that he would grow into an apprehension and appreciation of this grand all-embracing law."

He also said that a child often of twelve years is capable of understanding the principle of the lever just as well, or as perfectly, as did Archimedes of old Syracuse, and that if the conception is once implanted in the mind, it will become germinal and will, without watering and tending, bear fruit perennially through his life.

With a higher education in the direction just briefly indicated, the people will more generally come to understand the need of avoiding all empirical practice in the exact sciences and learn the truth that all mechanical processes, all constructive work, in fact all that goes to make up the sum and substance of our surroundings, are governed by exact laws which, if not observed, bring their own punishment for neglect.

DELANY'S SYSTEM OF FAC-SIMILE TELEGRAPHY*.

By Prof. Edwin J. Houston.

Fac-simile telegraphy embraces the methods by which chirography, outline sketches, maps, hieroglyphics, etc., produced at one end of a telegraphic line, are automatically reproduced at the other end. Such a system embraces a transmitting instrument at one end of a line and a receiving instrument at the other end. These instruments, though varied in form, consist for the greater part of similar surfaces maintained in approximately synchronous motion. The message is written or drawn on one of these surfaces, and is automatically reproduced on the surface at the other end of the line.

Numerous and various devices have been invented for the transmission and reproduction of fac-simile despatches. The principal of these may, however, be arranged under two heads. In one of these classes a pen or stylus, moved by the hand through a magnetic field, sends thereby a series of electrical impulses over the line that produces corresponding movements in a similar pen at the other end of the line. In such apparatus the handwriting or outlines are reproduced directly on the paper or other material that is placed on the surface of the receiving instrument.

In the other class, which embraces the greatest number of apparatus, the transmitting and receiving devices are of the same construction and consist of similar metallic surfaces, such for example as two cylinders maintained in approximately synchronous motion, and each provided with a pen or stylus that

* A paper read before the American Institute of Electrical Engineers, May 20, 1885. For the use of the cuts used in this article we are indebted to the *Electrician and Electrical Engineer*, New York.—(*Com. on Publ.*)

is caused to move over the surface. The pen or stylus is connected to the line so that the current passes from the transmitting instrument over the line and into the receiving instrument. The message to be sent is written on the surface of the transmitting cylinder, in any non-electrical conducting ink, and the surface of the receiving instrument is covered with ordinary Bain paper. When now the instruments are simultaneously set into motion, as long as the stylus or pen is in contact with the metallic surface of the transmitting instrument, it causes a continuous blue line to be traced on the Bain paper at the receiving end. When, however, the stylus or pen is moved over the surface of the non-conducting ink, the circuit is interrupted and the corresponding points on the surface of the receiving cylinder are left unchanged. The design traced on the transmitting instrument is thus reproduced on the receiving instrument in white on a blue ground.

Bain was the pioneer in fac-simile transmission. His devices, which were produced as early as 1843, belong to the second class of apparatus. To the same class belong the inventions of Bakewell in 1850, of Hunter in 1852, of Caselli in 1858, and of Bonelli. The devices of Lenoirs, of Sawyer, of Edison, of others may also be included in the same class.

The apparatus of Jones, produced 1855, and of Myers, belonged to the first class.

Thurrell, Müller and Chidly, in 1856, produced, jointly, an apparatus for fac-simile transmission, in which a magnetized point or roller was moved to-and-fro over the surface of the transmitting apparatus. While the magnetizing current continued to flow, a similar point traced a continuous line on the receiving surface, but whenever a break occurred, as, for example, by the non-conducting ink, the point was drawn away by a spring. The successive makes and breaks so obtained produced on the receiving cylinder the design traced on the transmitter.

Hitherto, the various systems of fac-simile transmission have failed in their successful commercial applications, either because of their unreliability, or from their great expense. When a single stylus or pencil was employed, as in the system of Bakewell, Caselli and others, the method was slow in operation and unreliable in its results. Bonelli's introduction of a multiple comb or stylus, in which a series of styluses or fingers at each station were

employed, connected between the two stations by a cable containing as many single conducting wires as there were fingers in the compound stylus at each station, increased the speed of transmission.

Bonelli's system, as will be readily understood, was a great improvement on the systems known at the time of its invention. Two difficulties, however, existed which have prevented its extensive use. These were,

(1.) The great expense of construction when the cable connected two distant stations, and,

(2.) The unreliability in the results attained, owing to the interferences in the strength of the momentary impulses sent through the separate wires of the cable, by induction in or by neighboring wires.

Mr. Delany has happily applied his system of synchronous-multiplex telegraphy to fac-simile transmission and has attained results that appear to render the actual commercial application of fac-simile telegraphy practicable. His system, briefly, consists in dividing a single telegraph wire, connected at each of its ends to a multiple comb, or series of styluses, into as many separate and practically distinct lines as the separate and distinct styluses at either end. The division of the single connecting wire into a number of separate lines is effected by his system of synchronous multiplex telegraphy, now so generally understood.

The means, whereby this application is made, will be better understood by an examination of *Fig. 1*, for which, in common with all the figures used in this paper, the author is indebted to the United States Letters Patent, granted to Mr. Delany for fac-simile transmission. In *Fig. 1*, is shown the transmitting and receiving apparatus connected with the synchronous distributor. In this figure, *X*, and *Y*, are the two stations. *A*, is the rotating disc, and *a*, its trailing finger or circuit completer, mounted on the axis of the disc *A*. *B*, is the circular table of insulated contacts. Eighty-four of these contacts are provided in this case, divided into six series of fourteen each.

The thirteenth and fourteenth contacts in each of these series is not shown as connected in the figure, these contacts being reserved for the synchronous correction of the apparatus, in accordance with the Delany synchronous-multiplex system.

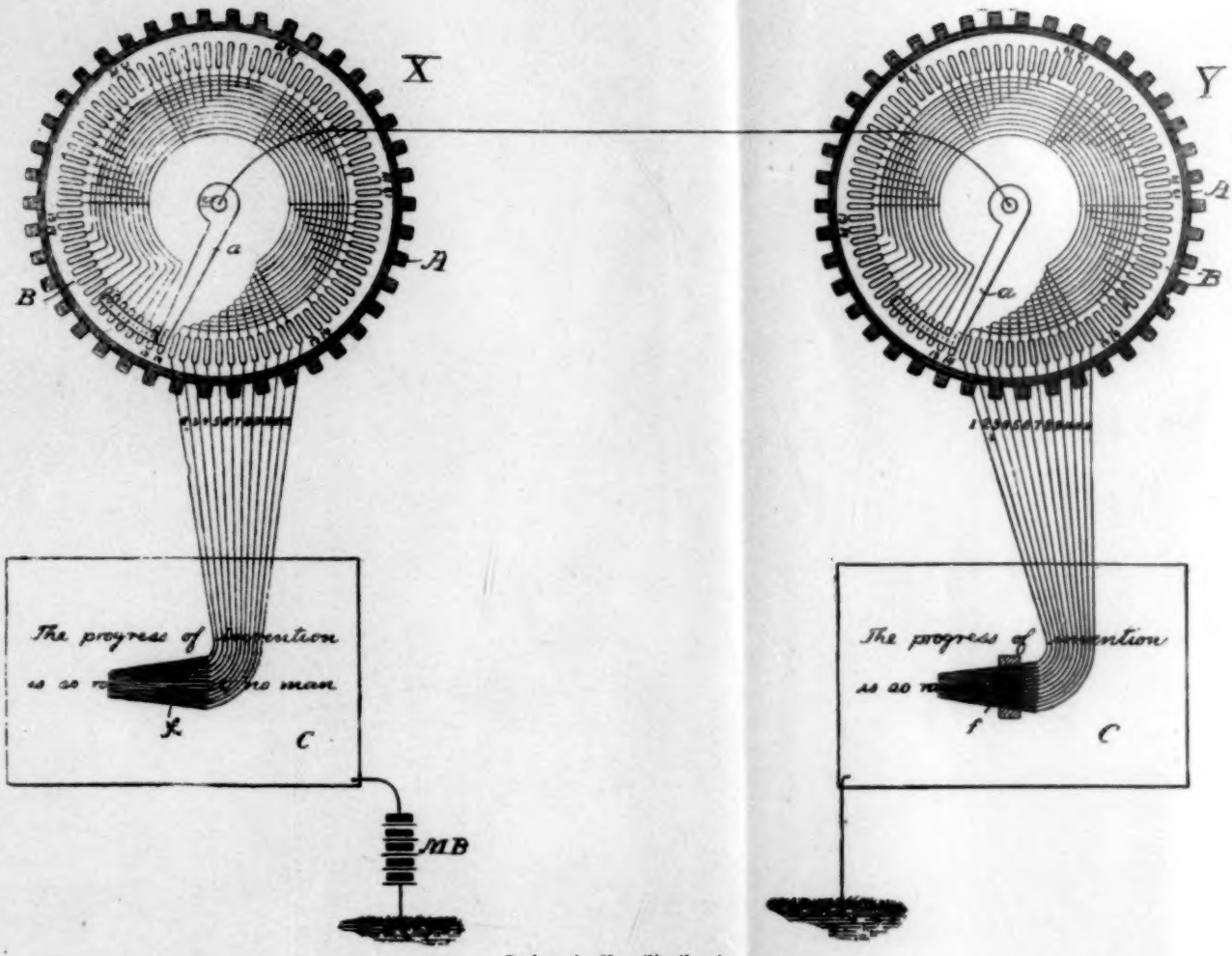


FIG. 1. Delany's Fac-Simile Apparatus.

Supposing the contacts in each of the six groups to be numbered from 1, to 14, consecutively, the number-one contacts in each of the six groups are connected together and to a line marked 1, at station *Y*, and the corresponding contacts similarly connected at station *X*, to a line marked *X*. The number-two contacts at each station are similarly connected to one another and to a line marked 2, and so with the other contacts, the thirteenth and fourteenth in each of the groups being reserved for the sychronizing of the line as already explained.

Each of the lines 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, so provided, is connected to an insulated finger or stylus *f*, that forms part of a comb that moves over the surface of the transmitting and receiving instruments *C*, *C*.

When, now, the synchronously moving fingers *a*, *a*, move over the contacts, they simultaneously rest on similar or corresponding contacts at each end of the line, thus completing the circuit from the insulated finger *f*, in said circuit 3, at station *X*, with the insulated finger *f*, in circuit 3, at station *Y*.

If the trailing fingers are rotated at a speed of say three times per second, the circuit will be completed over each of the twelve lines so provided between the two stations, eighteen times a second. At this rate a high speed of transmission is attainable. The insulated fingers are arranged, as shown in the figure, on a comb in close proximity to one another, but separated by some good insulating material. The plates *C*, *C*, on which these fingers rest, are maintained in approximately synchronous motion by clockwork or other suitable mechanism.

The battery *M B*, at one of the stations as *X*, has one of its poles connected to ground, and the other to the metallic plate *C*. Let us suppose now that *X*, is the transmitting station and *Y*, the receiving station, and that the message to be transmitted is written on the surface of *C*, at *X*, in some electrical non-conducting ink, while the surface of the receiving apparatus at *C*, is covered with a sheet of Bain or chemically prepared paper.

When now the ends of the fingers *f*, at *X*, are in direct contact with the metallic plate, the circuit of the battery *M B*, will be independently completed through each of the twelve lines, eighteen times per second through the fingers at *Y*, to the ground, and will thus produce the well-known blue marks or lines on the paper at

that station. When, however, the circuit is broken by the trailing finger at *X*, coming in contact with the insulating ink, the otherwise continuous line marked on the paper at *Y*, will appear broken, no discoloration appearing at such point. Whatever therefore is traced on the transmitting surface is automatically reproduced on

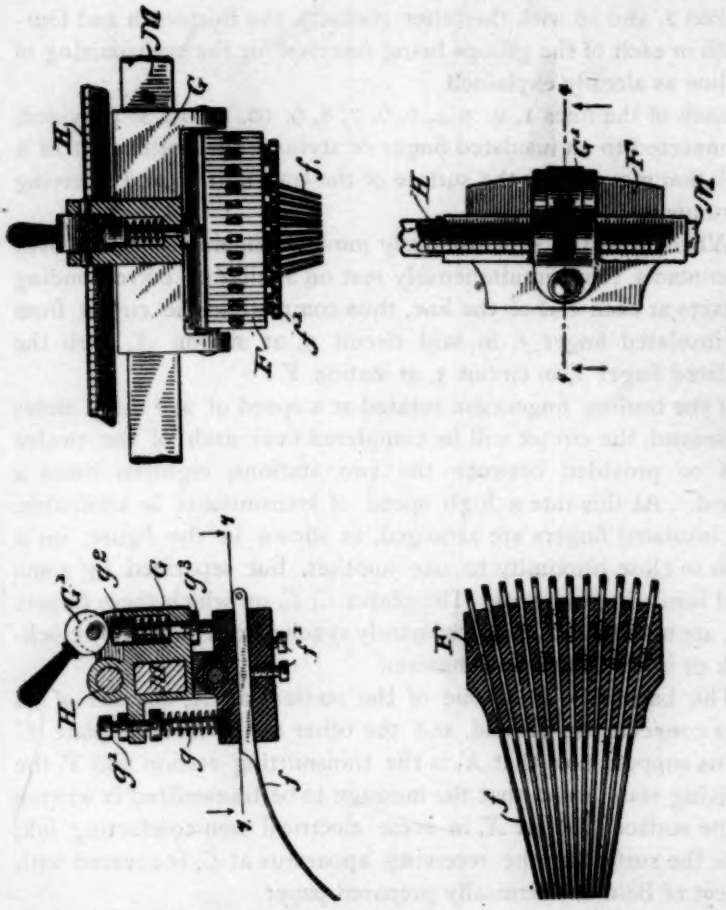


FIG. 2. Details of Multiplex Stylus or Comb.

the receiving surface in white lines on a nearly continuous blue ground.

Although any series of points in a straight line in the design traced on the transmitting surface, that were simultaneously touched by all the twelve separate and independent fingers, would

not be actually reproduced on the surface of the receiving apparatus as a rigorously straight line, since the electrical impulses would not be simultaneously sent over all the lines but over each in succession, yet in actual practice the completion of the circuits

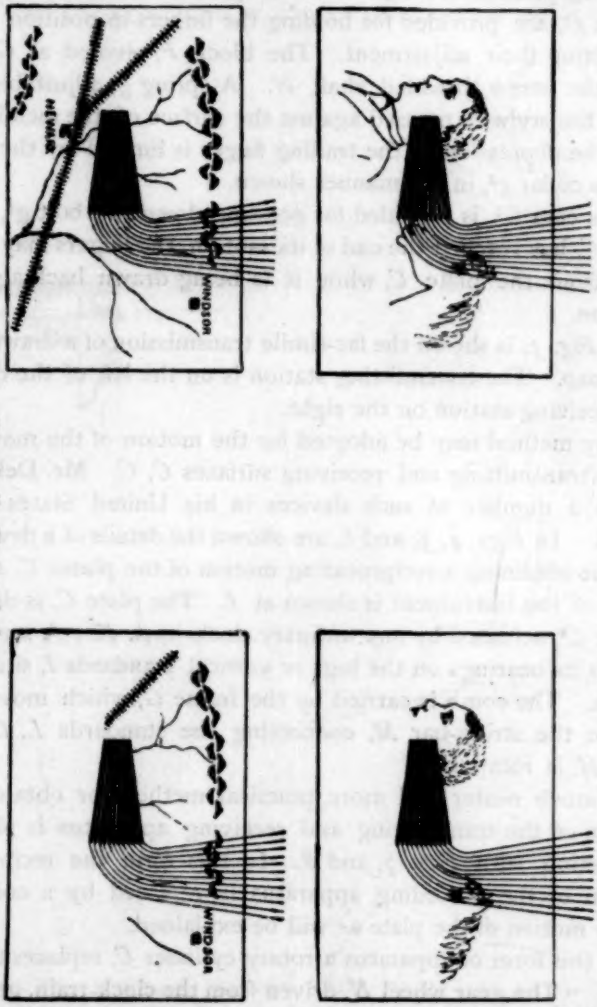


FIG. 3. Fac-simile Transmission.

in each of the separate lines occurs at such frequent intervals, that the deviation from the straight line in the case supposed is not discernible, and the effect is the same, as if the corresponding fingers at the two styluses were actually connected by separate and independent main lines.

In *Fig. 2*, are shown some of the details of the multiplex stylus or comb with its trailing fingers.

The separate fingers *f*, are mounted in the insulating block *F*, by being pressed through slots or apertures in said block. Set screws f^1, are provided for holding the fingers in position and for permitting their adjustment. The block *F*, pivoted at *G*, moves over the screw threaded shaft *H*. A spring *g*; adjustable by g^1, keeps the styluses pressed against the surface of the metallic plate *C*. The depression of the trailing finger is limited by the bolt g^2, and its collar g^3, in the manner shown.

The cam G^1, is provided for pressing down the bolt g^2, so that when *C*, has reached the end of its motion, the fingers may be held away from the plate *C*, while it is being drawn back again into position.

In *Fig. 3*, is shown the fac-simile transmission of a drawing, and of a map. The transmitting station is on the left of the drawing, the receiving station on the right.

Any method may be adopted for the motion of the movements of the transmitting and receiving surfaces *C*, *C*. Mr. Delany has shown a number of such devices in his United States Letters Patent. In *Figs. 4*, *5*, and *6*, are shown the details of a device suitable for obtaining a reciprocating motion of the plates *C*, *C*. The frame of the instrument is shown at *I*. The plate *C*, is driven by a rack C^4, actuated by any ordinary clock-work *K*. A screw shaft *H*, has its bearings on the lugs or vertical standards *I*, situated as shown. The comb is carried by the frame *G*, which moves laterally on the string-bar *M*, connecting the standards *L*, *L*, as the shaft *H*, is rotated

A much neater and more practical method for obtaining the motion of the transmitting and receiving apparatus is shown in connection with *Figs. 7*, and *8*. In this form the reciprocating motion of the preceding apparatus is replaced by a continuous rotary motion of the plate as will be explained.

In this form of apparatus a rotary cylinder *C*, replaces the plate *C*, *C*. "The gear wheel *N*, driven from the clock-train, gears with a wheel N^1, which is loose on the screw-shaft *H*. The wheel N^1, is normally locked on the shaft by a spring catch, *O*, which is pivoted in a collar on the end of a shaft and engages with the teeth of a gear-wheel, N^2, fast on the shaft."

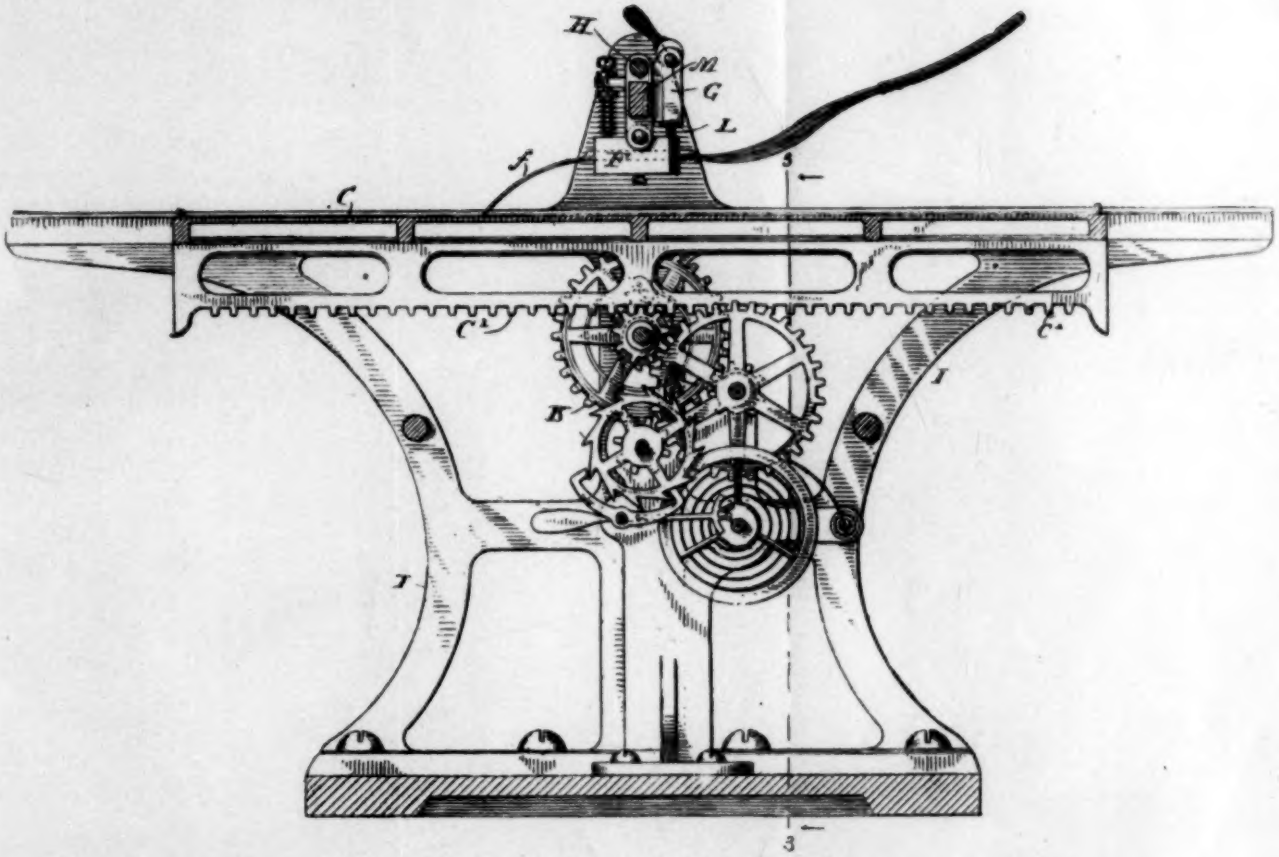
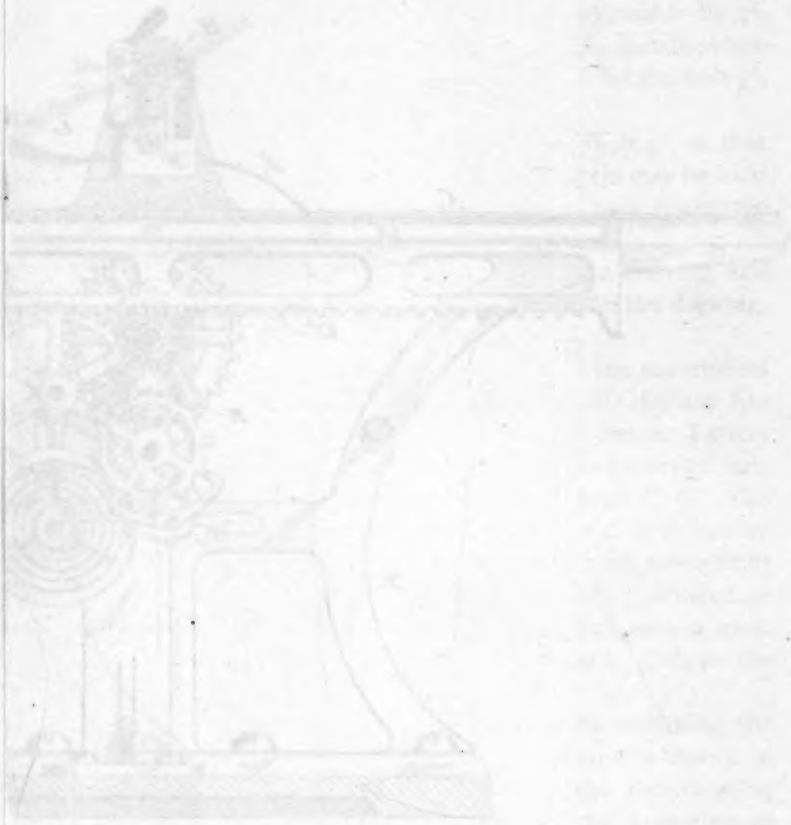


FIG. 5. Device for Reciprocating Motion of Transmitting and Receiving Apparatus.



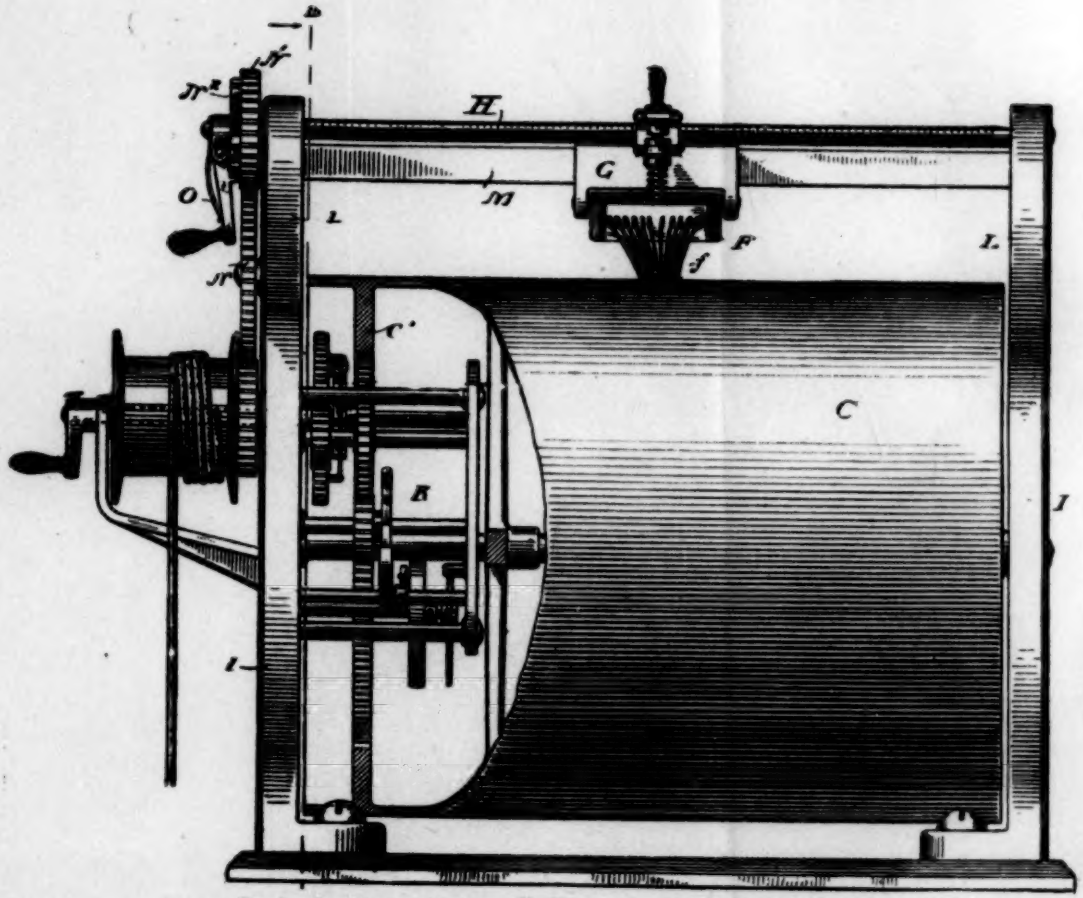
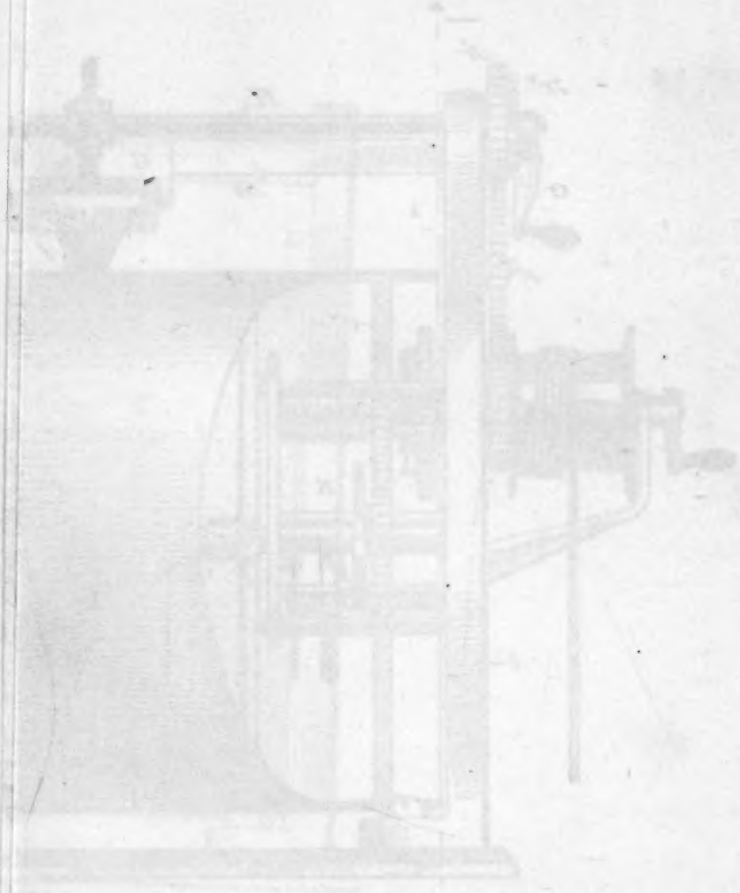


FIG. 7. Device for Rotary Motion of Transmitting and Receiving Apparatus.



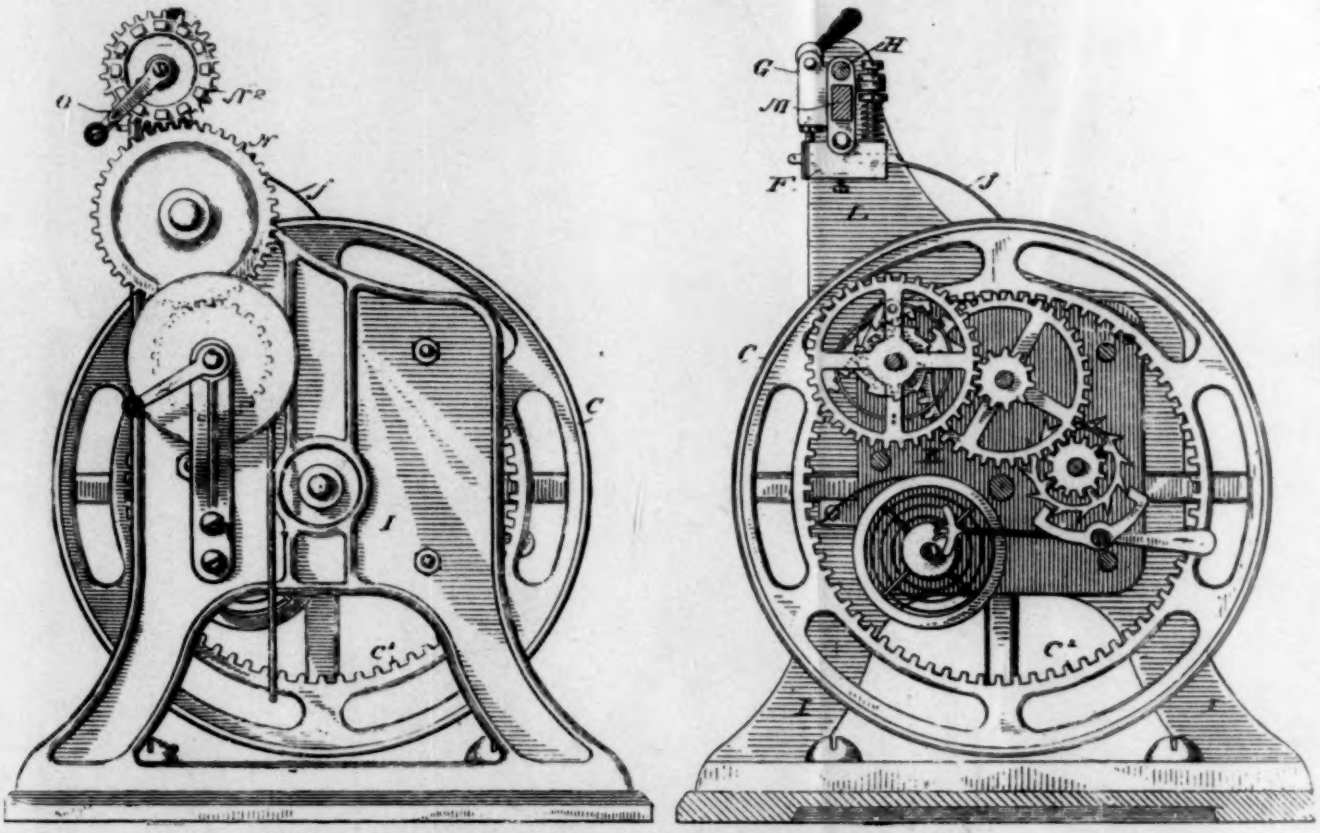
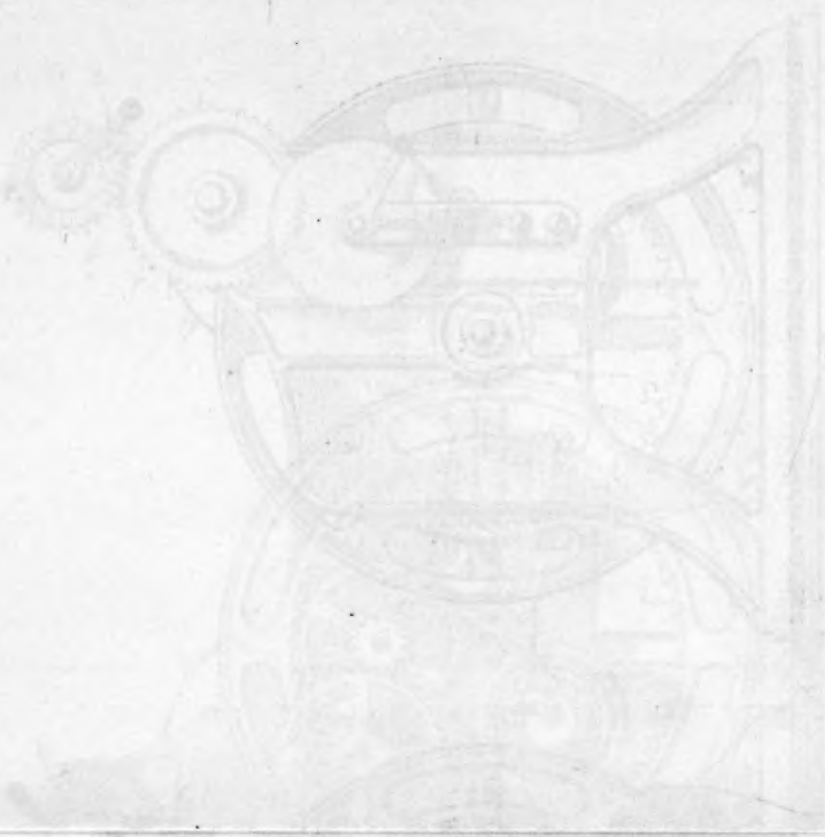


FIG. 8. Device for Rotary Motion of Transmitting and Receiving Apparatus.

FIG. 4. For Reciprocating Motion of Transmitting and Receiving Apparatus.



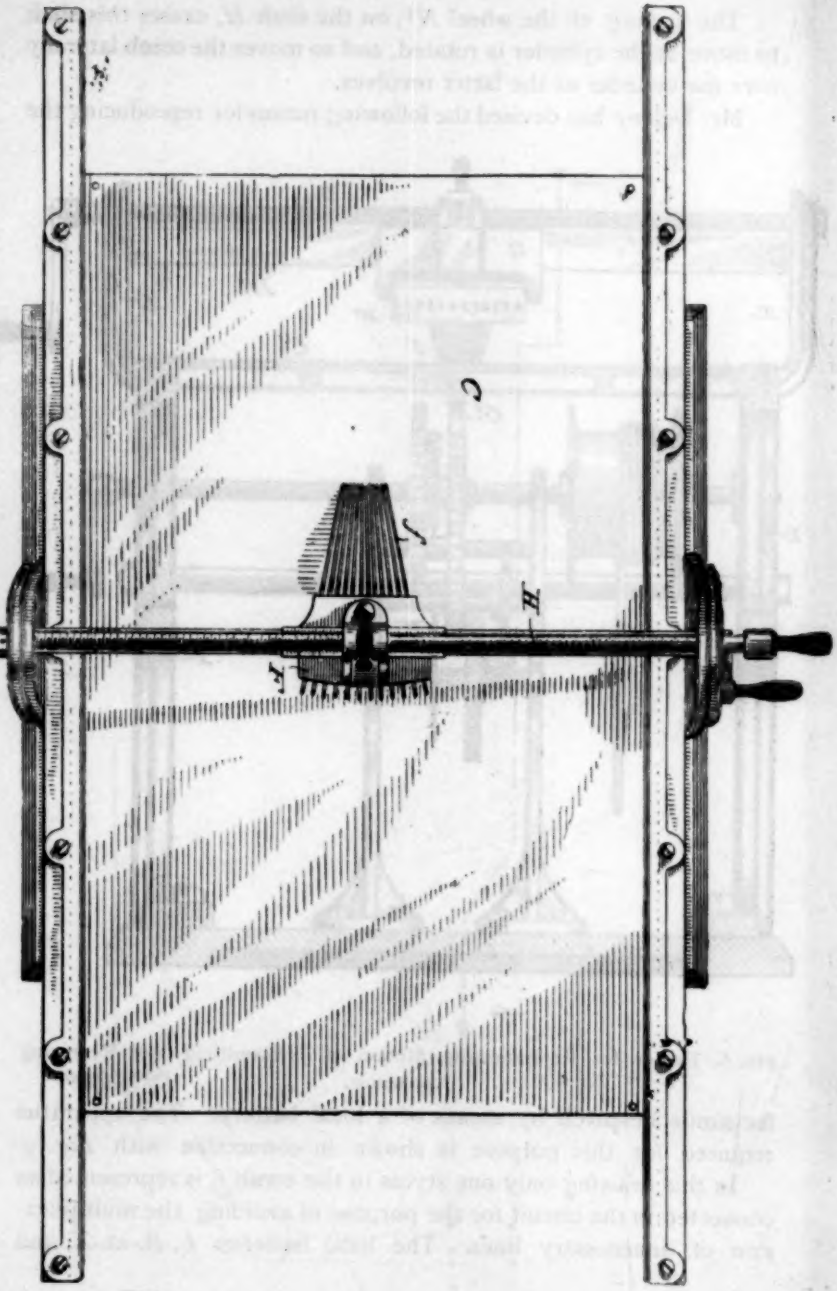


FIG. 4. For Reciprocating Motion of Transmitting and Receiving Apparatus.

The locking of the wheel N^1, on the shaft H, causes this shaft to move as the cylinder is rotated, and so moves the comb laterally over the cylinder as the latter revolves.

Mr. Delany has devised the following means for reproducing the

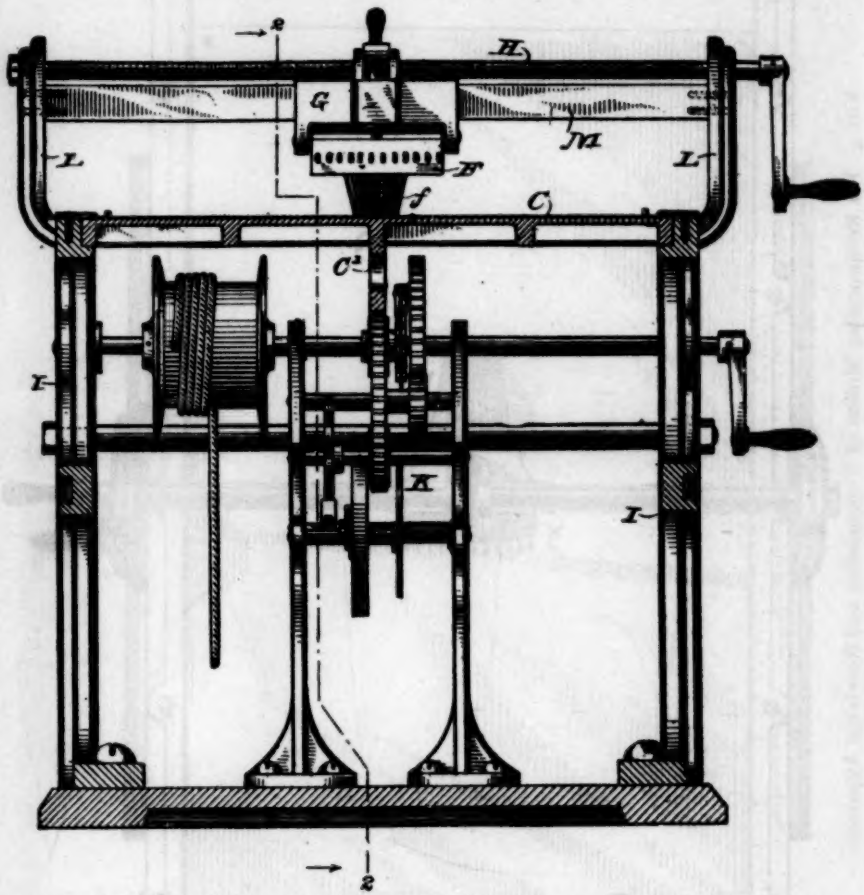


FIG. 6. Device for Reciprocating Motion of Transmitting and Receiving Apparatus.

fac-simile despatch by means of a local battery. The apparatus required for this purpose is shown in connection with *Fig.* 9.

In this drawing only one stylus in the comb f, is represented as connected in the circuit for the purpose of avoiding the multiplication of unnecessary lines. The local batteries L, B, at X, and

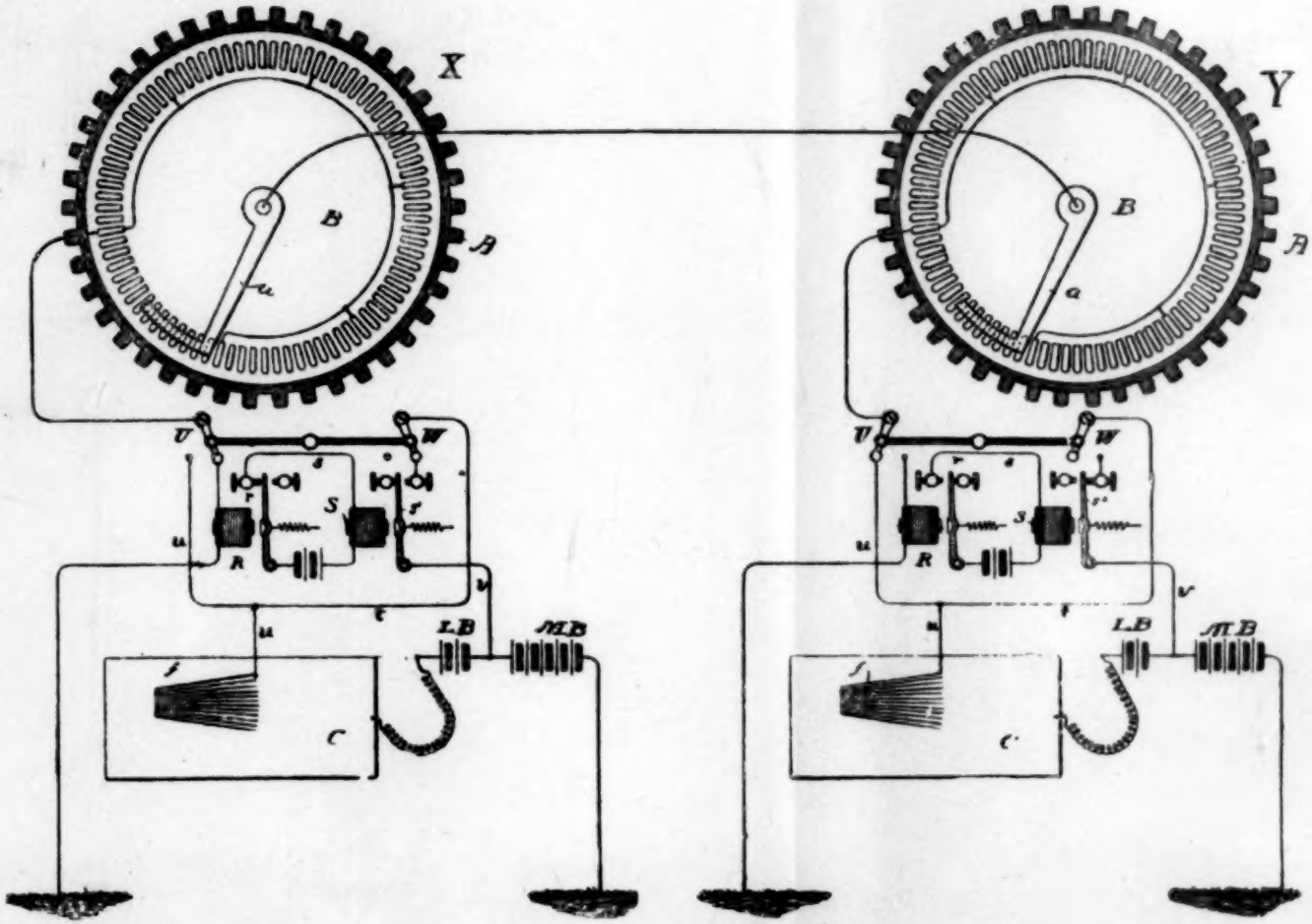
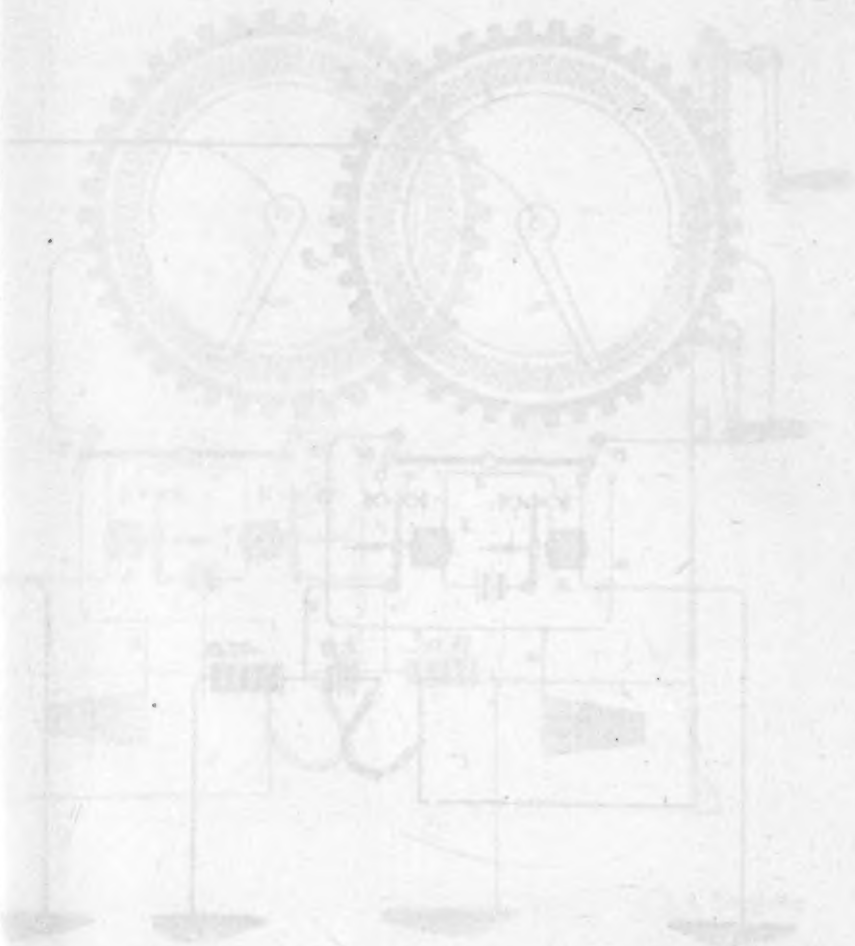


FIG. 9. Fac-simile Reproduction by Local Battery.



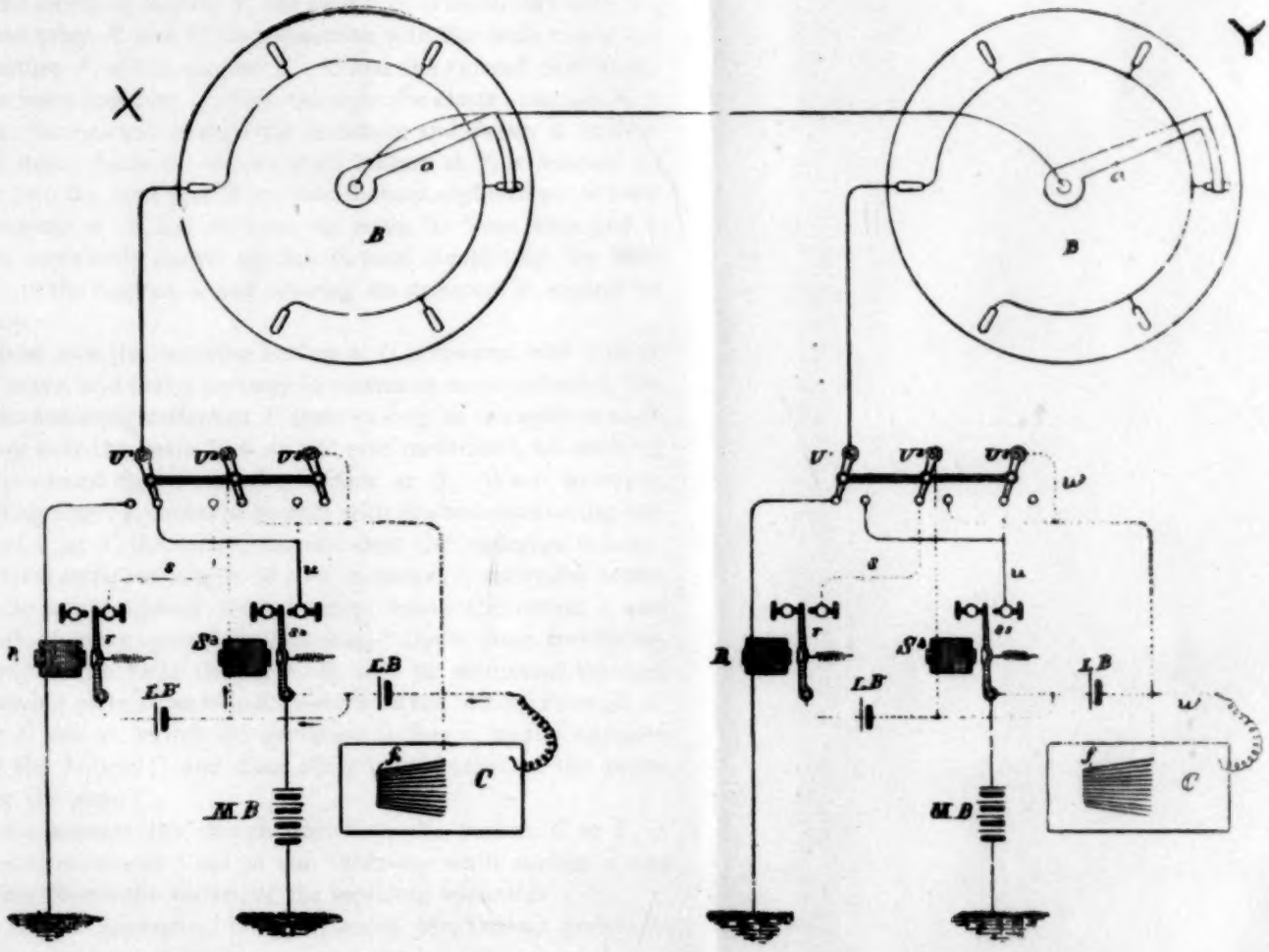
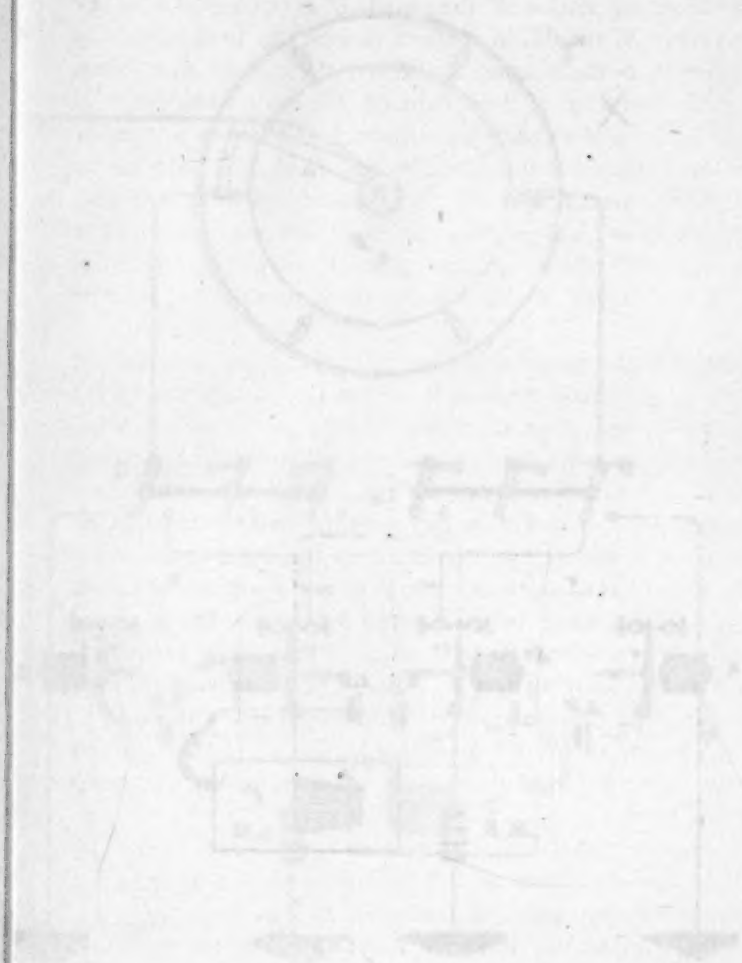


FIG. 10. Fac-simile Transmission. Improved Apparatus.



M, *B*, at *Y*, the transmitting station, connected as shown, send their current through the plate *C*, finger of the comb *f*, line *u*, switch *U*, to the table of circular contacts on *B*, and thence to the main line; the local circuit *t*, and the branch *v*, being both open.

At the receiving station *X*, the switch *U*, is connected with the coil of the relay *R*, and *W*, in connection with the back-contact of the armature s^1, of the magnet *S*. When the current that passes over the main line from *Y*, flows through the electro-magnet *R*, it energizes its core and attracts the armature and draws it against its front stop. Since the transmitting battery at *Y*, is sending its impulse into the main line at the rate of about eighteen per second. the armature of *R*, has no time to leave its front stop and is therefore constantly drawn against it, thus completing the local circuit *s*, of the magnet *S*, and drawing its armature s^1, against its front stop.

Suppose now the receiving surface at *C*, is covered with a sheet of Bain paper, and that a message is written in non-conducting ink on the transmitting surface at *Y*, then as long as the main current is passing over the main line at the rate mentioned, no marking will be produced on the receiving surface at *X*. When, however, the trailing finger *f*, comes in contact with the non-conducting line traced on *C*, at *Y*, the battery current over the main line is interrupted for a sufficient length of time to permit *r*, under the action spring, to come against its back-stop, break the circuit *s*, and permit s^1, to move against its back-stop. Under these conditions, the circuit of the local battery *L*, *B*, will be completed through the receiving plate *C*, as follows, viz.: from the battery through *C*, "finger *f*, line *ut*, switch *W*, armature s^1, line *v*, to the opposite pole of the battery;" and thus effect a coloration in the paper covering the plate *C*.

In this manner the design traced on the surface *C*, at *Y*, is reproduced in colored lines on the otherwise white surface of the paper that covers the surface of the receiving apparatus.

The form of apparatus, however, which Mr. Delany prefers, is shown in connection with *Fig. 10*.

As shown in this figure the switches U^1, U^2 and U^3, at each end of the line, are arranged for transmission from *X*, to *Y*. As before connections with a single group of contacts only is shown.

The transmitting battery *M*, *B*, has one of its poles connected

to ground and its other pole to the armature s^2, and the magnet S^2. The front stop of this armature is insulated; its back-stop is connected to the main line, through the line u^1, switch U^1 and the circular table of contacts. The local battery L, B, has its circuit closed under normal conditions through the path indicated by the arrows. The armature s^2, is therefore drawn against its insulated front stop, whenever the circuit between the finger f, and the plate C, is uninterrupted. When, however, this circuit is broken or interrupted by the finger f, coming in contact with the non-conducting ink on transmitting surface at X, this local circuit is interrupted, s^2, moves to its back-stop and the current from the main battery M, B, will pass through the line u^1, switch U^1, and over the main line to Y. When, after passing through the contacts and the switch U^1, it flows through the coils of R, and thence to earth. The armature r, of magnet R, is thereby drawn against its front stop, thereby breaking the circuit of the local battery L, B^1, which normally is completed through r, line s, switch U^2 and magnet coil S^2. When the impulse sent from X, breaks this circuit in the manner described, the armature of S^2, moves against its back-stop, thus completing the circuit of the local battery L, B, through the armature s^2, line u^1, switch U^3, u^2, f, and plate C. If, therefore, the surface of the receiving apparatus is covered with a sheet of Bain paper, a discoloration is produced thereon, which reproduces the design traced on the transmitting apparatus.

From this brief description of the apparatus which the author has drawn mainly from the United States Letters Patent before referred to, it will readily be seen that Mr. Delany has produced a system of fac-simile telegraphy that possesses all the requisities for successful commercial application.

CENTRAL HIGH SCHOOL,
Philadelphia, May 18, 1885.

ATMOSPHERIC CURRENTS.—A balloon ascension by the Tissandier brothers showed some interesting particulars in regard to the stratification of aërial currents. For 800 metres above the earth's surface the wind blew from the southeast; at the upper surface of the fog there was a counter-current, with a thickness of about 350 metres, from the northwest. At a still greater height there was a third current from nearly the same direction as the surface wind. The currents were all feeble, and the balloon went back and forth over Paris in precisely opposite directions.—*Les Mondes, Nov. 8, 1884.*

C.

THE TATHAM DYNAMOMETER.

The Tatham dynamometer, constructed for the FRANKLIN INSTITUTE last year, which measured the power consumed by the dynamo-electrical machines tested by a Committee of Judges in June last (see report in Supplement to the JOURNAL OF THE FRANKLIN INSTITUTE, for November, 1885,) is capable of measuring 100 horse-power. The largest machine then measured required 70 HP.; the smallest ·23 HP.

It occupies a floor space of about 6 feet by 4 feet, and is about 7½ feet high.

The cast iron bed-plate rests upon heavy castors and is provided with levelling screws. Upon this bed-plate are erected the two main frames, bolted together at convenient places and united at the top by a cast iron arch, from which the scale beam is suspended. A movable *A* frame in two parts is hinged to the bed-plate, and when in position, holds firmly the journal boxes of the outside bearings of the two middle shafts. When opened, it gives liberty to change the outside pulleys, or the belts which run upon them.

This dynamometer is upon the same principle as the small machine described in the JOURNAL OF THE FRANKLIN INSTITUTE, for December, 1882, but differs from it, in that the single pulley upon the first motion shaft of the small machine is replaced by three pulleys in the large one.

(Reference being had to the skeleton sketch herewith) the reasons for this change were:

(1.) To reduce the height of the machine.

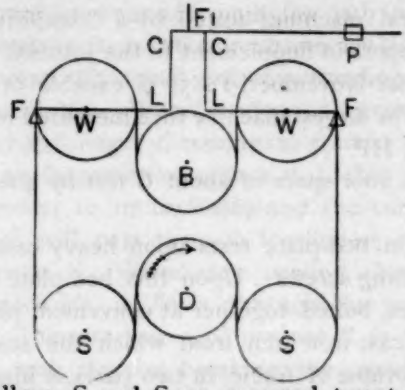
(2.) To give the journals of the pulley shaft *D* a fixed position, while the two outside lower pulleys are used to tighten the belt.

(3.) To make the two pulleys *B* and *D* run in the same direction and with the same speed.

All of the pulleys are cast iron plate pulleys, turned all over inside and out and accurately balanced. They are twelve and a-half-inches face and are upon cast steel shafts, two-inches diameter, running in brass boxes, which are from six to eight inches in length.

The pulley *D* is twenty-five-inches diameter, crowned and placed upon the first motion shaft, which receives power from an outside

belt. The pulley *B*, twenty-five-inches diameter, ground perfectly true and flat, is upon a shaft which conveys the power to the machine to be tested. In measuring a motor, its power is applied to the pulley *B*.



The two pulleys *S* and *S* are crowned, twenty-one-inches diameter and their shafts run in bearings which are upon vertical slides regulated by screws. The vertical movement of these pulleys regulates the tension of the belt. The pulleys *W* and *W* are twenty-one-inches diameter, slightly crowned, and their shafts run in bearings upon the two lever frames *L F* and *L F*, each of which has its fulcrum in a pair of knife edges at *F*, resting upon the main frame. The inside ends of the lever frames are suspended by links *L C* and *L C* to the scale beam *F P* at equal distances on either side of the principal centre of the beam. There are two adjustments to each of these lever frames. (1.) Two micrometer screws adjust the position of the centre of the pulley, so that the line of effect of a belt hung on it on the outside will pass through the fulcrum, and no addition of weight to the belt will affect the scale beam; which is experimentally proved. (2.) The position of the knife-edge suspended to the link is adjusted so that the scale beam weighs accurately any weight suspended by a piece of belt hung over the inside of the pulley.

The endless belt used was a four-ply gum belt, 12-inches wide and ·26-inches thick. The breaking strain was 12,000 pounds. It was originally intended to use a three-ply belt, ·21-inches thick, and the pulley *B* was constructed so that the effective diameter would be 25·21 inches, giving a delivery of belt of 6·6 feet per revolution. The arrows indicate the movements of the belt.

It will be seen by the construction, that the pulley *B* is actuated by the difference of the tensions of the two parts of the belt tangent to it, and that the scale beam weighs the same difference of tensions of the same parts tangent to the pulleys *W* and *W*.

As the accuracy of weighing was the vital requisite, the construction of the dynamometer was intrusted to the celebrated scale makers, Messrs. Fairbanks & Co. The scale beam was graduated by Messrs. Brown & Sharpe in 600 divisions of $\frac{1}{10}$ inch each representing a half pound with the travelling poise used. On this poise is a small beam graduated in hundredths, so that the small poise upon the small beam is capable of weighing $\frac{1}{200}$ of a pound when the machine is in motion. The more rapid the motion the more delicately can the weighing be accomplished.

In testing dynamo electrical machines, the resistance measured being very uniform, it was only necessary that the belts used should be of even thickness and free from lumpy splicings, to get rid altogether of the tendency to dance, which otherwise afflicts the beams of belt dynamometers

The fastest speed made by the dynamometer in June last was 1,700 revolutions per minute, which gave the belt a speed of two and one-eighth miles per minute, or about one-eighth the velocity of a rifle ball. The fastest speed of any test was about 1,400 revolutions (9,240 feet of belt) per minute continued for ten consecutive hours, during which the belt ran over 1,000 miles.

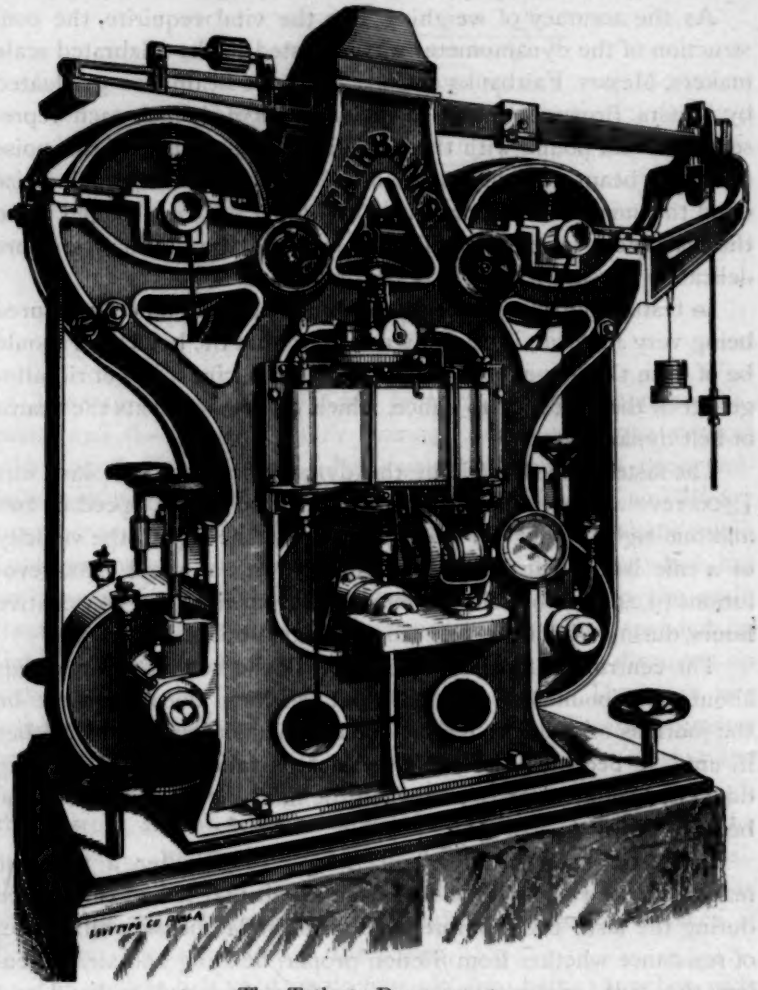
The centrifugal force tending to break the belt at this speed, is about 1,350 pounds on each part, but this force does not come on the journals or pulleys: it is confined to the belt itself, and stretches it, until it becomes slack. The slack is taken up by screwing down the pulley *S*, or *S*, and when the machine slows or stops the belt *is* tight.

In getting the "friction" of the pulley *B*, after a test, the machine was run light at the same speed that it had run loaded during the test; thus comprehending in similar measure all sources of resistance whether from friction proper, bending and straightening the belt, or air currents. The force required to bend and straighten the belt was sensibly affected by the temperature of the air.

Before the dynamo tests began, it was observed that the air currents, caused by the rapid movement of the belt, interfered with

the functions of the scale beam, and it was found necessary to place sheet iron roofs over the upper pulleys. The lubrication is accomplished by an automatic feed, under control.

The machine is provided with a counter, which registers the



The Tatham Dynamometer.

number of revolutions up to 1,000,000. The number of revolutions per minute can be observed to within a fraction of one revolution.

It is also provided with apparatus to record the power measured. This, however, was not used during the tests, as direct weighing

was found so convenient, and the results could be so quickly calculated. At the end of the scale beam is a vertical rod attached below to an iron cylinder, which floats in mercury in an iron cylindrical pipe. The beam being balanced, any force tending to raise it, lifts the cylinder out of the mercury proportionally. This motion, multiplied by levers, is communicated to a pencil point, which moves vertically one-eighth of an inch to the pound, and records the weight upon a paper band moving horizontally one inch for every 100 revolutions, and recording them. This automatic registration of weight is applied only to the fractions of weight between the even fifty pounds, the principal part of the weight being hung at the end of the scale beam in the usual way.

By confining the registration to this small excess, it is registered on the large scale above mentioned. The calculation of HP measured is very simple. Multiply the number of revolutions by the weight (in one-half pound) on the scale and divide by 10,000. The result is HP and decimals This, however, supposes a belt twenty-one hundredths of an inch thick. A thicker belt requires a correction in accurate work.

Not the least interesting portion of the report of the Committee referred to, is that relating to the "Calibration of the Dynamometer." In order to prove whether or not the dynamometer measured correctly the power transmitted through it, it was used in the determination of the mechanical equivalent of heat on an enormous scale. The water churn used was a cylinder, 3 feet diameter and 3 feet long, holding 1,223 pounds of water. In the continuous method, devised by Professor Marks, the water entered the churn at nearly uniform temperature and left it at nearly uniform temperature, about 15·5° Centigrade higher than it entered. The operation continued for three hours. The first half hour was occupied in bringing the exit water to uniform temperature, when the experiment proper began and continued for two hours and a-half, during which over five tons of water passed through the churn and was raised about 15·5° Centigrade by the continued exertion of about forty-six horse-power.

The result as calculated was:

Mechanical equivalent for 1° Centigrade, . . 1391·05 foot pounds.
Mechanical equivalent for 1° Fahrenheit, . . 772·81 foot pounds.

Dr. Joule's last determination was 772·55 foot pounds, and Prof. Rowland's is higher.

W. P. TATHAM.

The BEHAVIOR of STEAM in the CYLINDER.

The Committee on Publications:

Gentlemen:—I observe in Chief Engineer Isherwood's account of certain experiments on steam engines, published in your latest issue, that he continues to claim the "discovery that the cylinder of a steam engine acted alternately as a condenser and as a boiler, condensing a portion of the entering steam during its admission, and revaporizing the resulting water of condensation during the period of expansion and during the exhaust stroke, which phenomena were caused wholly by the interaction of the metal of the cylinder," etc. "This discovery," he says, "was made a great many years ago by him, and stated and used in his published professional writings," and he refers to his "Engineering Precedents," Vol. II., 1859; and to his "Experimental Researches in Steam Engineering," 1861 and 1863. He adds, that "no one contested the discovery, or even used it until quite lately." I presume he herein alludes to my paper, "On the Behavior of Steam in the Cylinders of Locomotives during Expansion," published in the minutes of "Proceedings" of the Institution of Civil Engineers, England,* of which I enclose to you a copy; and this reference must be my apology for asking you to publish this letter in reply.

In the copy of my paper enclosed, I have summarized the results of my experimental investigations on the action of steam in the cylinder, which were conducted in the year 1850, and the results of which were published in the course of the year 1852†, or seven years before Mr. Isherwood even made or published his experiments bearing on the question. In the enclosed paper, I have briefly restated the evidence and arguments employed and published by me in 1851–52, in investigating the behavior of steam in the cylinders of locomotive steam engines, showing, amongst other things, the formidable losses by condensation and re-evaporation of steam in cylinders, and the augmentation of the

* See Vol. lxxii, of the Minutes, Session, 1882–83, page 275.

† See *Railway Machinery*, 1851–56. Blackie & Son, pages 77 to 85; also a paper on the "Expansive Working of Steam in Locomotives" in the "Proceedings of the Institution of Mechanical Engineers," 1852, pp. 63, 105.

loss in proportion to the degree of expansion to which the steam is worked; and showing that without the adoption of special means for preventing or lessening condensation within the cylinder, expansive working, by cutting off earlier than from one-half to one-third of the stroke could not be practised with economy. If you will allow me, I will quote a paragraph direct from *Railway Machinery*, in which I specially announce what Mr. Isherwood calls *his* discovery seven years before he made or published his experiments.

"In general, it is to be concluded that, first, when the cylinder is thoroughly immersed in the hot bath of the smoke box, the temperature of which is commonly much higher than that of the steam, the quantity of water existing as steam during expansion is virtually constant. Secondly, when the cylinder is placed nearly or entirely beyond the influence of the heat of the smoke box, or is protected only in the usual manner by felting and plating, the quantity of water as steam varies very considerably during expansion. It suffers a rapid and transient diminution during the first stages of expansion, and amounts to an excess over the initial quantity, which increases uniformly as the ratio of expansion is prolonged; till for a final volume of about three and a-half times the initial volume, when the steam is cut off at fifteen per cent., the excess amounts to fifty-seven per cent. of the weight of sensible steam cut-off, or otherwise to thirty-six per cent. of the gross quantity of steam admitted. The foregoing results are directly contrary to what might have been anticipated as, at first sight, they appear to show that the less protected the cylinders, the more work is done with a given initial quantity of steam. In the inside cylinder, so far from any apparent evaporation or accession to the total weight of the steam during expansion, the quantity is at least not more than constant, and is, in fact, slightly reduced during expansion. The outside cylinders on the contrary show, by the great excess of steam at the end of expansion, very significant amounts of factitious evaporation. In this case, as in that of the low speed diagrams, the difference is referable to a primary condensation of the steam during admission, by which water is formed, whilst the temperature of the cylinder is raised. After suppression, and when the steam temperature falls by expansion below the newly-acquired temperature of the cylinders, the hot water flashes into steam in

virtue of its own heat and that of the cylinder, according to the law of the maximum density and pressure for the temperature; and what appears, at first sight, to have been positively one advantage of unexposed cylinder, in the auxiliarly evaporation during the later stages of expansion, is nothing more than a partial resuscitation of the precipitated steam, as a compromise for lost initial action. The greater the proportion of expansion, the greater is the final excess of steam, as the extreme temperatures become more widely different; and, moreover, for the higher degrees of expansion smaller absolute volumes of steam are admitted, for which there is always the same cooling superficies of cylinder; and this is relatively greater, of course, as the period of admission is reduced. In the enclosed inside cylinder, on the contrary, bathed in hot air, or enveloped in cinders, actually hotter than the steam that passes through them, the initial pressure of the steam as it enters the cylinders, is maintained in its integrity, as, even for the greater expansions, there appear no symptoms of a resurrection of steam. The evidence goes rather to show that the steam is superheated during its passage through the steam pipes previous to admission."*

I have supplied direct evidence of alternate condensation and re-evaporation by direct comparison of the quantity of steam cut off, according to the indicator diagram, and the quantity of water measured from the tenders of locomotives—not necessarily in terms of their weight, as Mr. Isherwood appears to insist on, but in terms of the volume of water, as steam and water from the tender, which are, of course, exact measures of quantity. In fact, measurement by volume is the basis of the investigation. If, as he implies, he weighed the sensible steam, how did he weigh it? And if he did weigh it, why is weight a better measure than volume? I have given very full details of experiments and observations on the performance of locomotives to prove by direct measurement, quantitatively as well as qualitatively, the pregnant fact of the alternate condensation and re-evaporation of steam. In the case of No. 42 express locomotive on the Caledonian Railway, in 1850, and several other locomotives. The results were published in detail in 1852.†

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* *Railway Machinery*, page 82.

† See *Railway Machinery*, 1850–56, pages 144 to 151; also, "Proceedings of the Institution of Mechanical Engineers," 1852, pages 120 to 126.

Then Mr. Isherwood says: "No one contested the discovery, or even used it, until quite lately." I may say, for my part, that since the first publication of my experiments and deductions, in 1851–52, I have repeatedly announced the fact of alternate condensation and re-evaporation as a matter first demonstrated and established by myself.* Mr. Isherwood appears, also, to forget his correspondence with Mr. G. A. Hirn, in 1879, respecting the claim of Mr. Isherwood, in the JOURNAL OF THE FRANKLIN INSTITUTE, for July, 1878, to his having published for the first time his "discovery." M. Dwelshauvers Dery published the correspondence in 1879,† from which it appears that Mr. Isherwood was anticipated by Mr. Hirn, by several years, in 1857, although Mr. Hirn was again anticipated by me in 1851–52. Mr. Isherwood is therefore in error in stating that "no one contested the discovery."

As the question of prior discovery has been raised, perhaps, Gentlemen, you will allow me to quote a disinterested authority, Mr. Anatole Mallet, past President of the Institution of Civil Engineers of France, who has kindly recognized my priority on this question in his communication to that institution in 1877, on the utilization of steam in locomotives: *Etudes sur l'Utilization de la Vapeur dans les Locomotives et l'Application à ces Machines du Fonctionnement Compound*," in the *Mémoires de la Société des Ingénieurs Civils, 1877*. In this paper, Mr. Mallet says: "Mr. D. K. Clark was the first experimentalist who, by practical evidence, traced to its true source the excess of the quantity of steam; or the water equivalent of it, in the cylinder, at the end of the expansion. He demonstrated that a portion of the steam, when admitted at each stroke, was condensed, and that it was in part re-evaporated at the end of the expansion; and that by this destroying process, the efforts at economy by cutting off early and expanding were baffled, insomuch that it was practically impossible with economy to cut off earlier than at one-third of the stroke." Mr. Mallet proceeds to say: "In these publications (already named in the second foot note), has been for the first time so

* See *The Exhibited Machinery* of 1862, page 300; *Steam and the Steam Engine*, 1875, page 267; *A Manual of Rules, Tables and Data for Mechanical Engineers*, 1877, page 880.

† See *Revue Universelle des Mines*, vol. v, 1879, page 494.

completely elucidated the behavior of steam in the cylinders of locomotives, and the part that is played by the condensation of the steam during admission—a characteristic phenomenon which gives the key of the difference which always exists between the practical expenditure of engines and the calculated consumption, and the reality of which, strange to say, many engineers, otherwise very distinguished, really believed, could be contested ten or twelve years after the publication of these works" (p. 852).

See a series of articles in behalf of Mr. Hirn's claim, on "Les Decouvertes Récentes Concernant la Machine à Vapeur,"—"Recent Discoveries in the Steam Engine," by M. Dwelshauvers Dery, in the *Revue Universelle des Mines*, tomes iv., v. and vii., for 1878, 1879 and 1880. Also several contributions by Mr. O. Hallauer, and others, to the *Bulletin de la Société Industrielle de Mulhouse*.*

D. K. CLARK.

8 BUCKINGHAM STREET,
ADELPHI, LONDON, ENGLAND,
October 22, 1885.

BOOK NOTICES.

SPECIALISTS' SERIES, VOL. 2.—GAS ENGINES. By Wm. Macgregor. Price, $3.00. London: Symons & Co.; New York: D. Van Nostrand.

This is an unusually satisfactory addition to the technical literature of the day.

The progress of invention, from the early attempts to produce a successful motor by the combustion of gunpowder, and of hydro carbons—to the more recent inventions of Clerk and Otto, is clearly traced.

The explanation of the mechanical construction and theory of each type of engine is clear and satisfactory.

Seven plates are appended, which contain forty-one sections, and explanatory views, including indicator diagrams.

Chapter 9, pp. 210 to 225, contains a condensed synopsis of a paper by Prof. W. E. Ayrton, F.R.S., and John Perry, M.E., read before the Physical Society of London, "intended to teach practical men a method of obtaining information from the indicator diagrams of a gas engine." Taking the Otto engine, as typical, its action is explained through a single cycle of its operation, the indicator diagram, and its uses are also explained fully.

The nature of the working fluid is shown by tables constructed by Messrs. Ayrton and Perry, followed by careful analysis of the diagram tables, etc.

*In a letter received since above was in type, Mr. Clark makes the following additional references to establish his claims to priority, viz., A Rudimentary Treatise on the Steam Engine, 1879, Lockwood & Co.; and the article, Steam Engine, Encyclopædia Britan., eighth edition. [Com. Pubs.]

The stimulus given to everything relating to the uses of gas by the success of the electric light, has resulted in the invention of a number of gas engines, some of them of remarkable merit. To enable mechanical engineers to correctly proportion and build these machines, such a work as this was much needed, and will result, doubtless, in the production of still better engines than those now in operation. M. G. W.

A CATALOGUE OF CHEMICAL PERIODICALS. By H. Carrington Bolton, Ph.D. From the Annals of the New York Academy of Sciences. Vol. iii., Nos. 6 and 7.

In this catalogue may be found a very full list of the titles of the principal chemical periodicals of twelve countries. The titles of some periodicals that pertain also to pharmacy, physics and the application of chemistry to the arts and manufactures are found in the list. The author has endeavored to furnish a complete bibliography of periodicals devoted chiefly to chemistry and refers any one desiring a more comprehensive bibliography of scientific works to his *Catalogue of Scientific and Technical Periodicals, 1665–1882*, published by the Smithsonian Institution, or to the *Catalogue of Scientific Serials*, by Mr. S. H. Scudder (Cambridge, 1879).

The arrangement of titles is alphabetical, with full and useful cross-references. A geographical index of countries and cities is added.

The value of Dr. Bolton's useful work will be recognized by all chemists, but can be fully appreciated by those alone who have learned by experience how much such catalogues and special indexes are needed. L. B. H.

A MANUAL OF THE THEORY AND PRACTICE OF TOPOGRAPHICAL SURVEYING BY MEANS OF THE TRANSIT AND STADIA. By J. B. Johnson, C. E.

This is a much needed work. The methods treated of have long been commonly used in Europe; but, although adopted here upon some important government and other surveys, their use has been chiefly restricted to a few engineers engaged upon such work, and whose occupation has justified them in specially investigating the subject. The accounts of these surveys, which have from time to time appeared in the engineering periodicals, have elicited a growing demand for a comprehensive treatise upon the subject; a demand which has hitherto remained unsatisfied, unless we except the little book of Mr. Winslow, lately reprinted from *Van Nostrand's Magazine*.

The present volume goes a great way toward supplying this "long-felt want." The needed information is given with great conciseness, and yet with a fulness sufficient for those acquainted with the ordinary methods of topography, and for these the book is intended.

The few formulæ given cover the case completely, and are so simply and clearly put as to be easily understood and memorized.

The author has been remarkably successful in accomplishing, within the narrow limit of about 100 pages, his three-fold object, as stated in the preface: first, to instruct the student, and afterward to aid him in the field; second, to furnish the practising engineer with such an account of the theory and method as would enable him, "without other instruction," to "prepare his instruments and do the work in good shape;" and, third, to furnish the necessary reduction tables and directions for plotting.

The first chapter gives the theory of stadia measurements, with the necessary formulæ for obtaining, at one sight, horizontal angles and distances, and elevations. The second describes the instruments used, the transit and the stadia, with the features required and desirable to adapt the former to this method of work. The third explains the application of the method to general topographical surveying, including the field work, the reduction and plotting of the notes, and the final preparation of the map. The fourth gives corresponding instructions as to railroad work, and the fifth as to other surveys, such as those for canals, drainage basins, bridge and town sites, geological surveys, etc. The sixth and seventh chapters give briefly some data as to the probable accuracy and cost of the survey with transit and stadia, and a comparison of the relative advantages of that method with those of the use of the plane table. The eighth chapter, treating of baseline measurement, triangulation and azimuth, seems properly a part of, or supplement to, the preliminary part of the third. The ninth and last chapter is devoted to the preparation of the map.

If we were asked to name a desideratum for a second edition, we should ask for more numerous and better cuts. These would not only make the book much more easy of use to the engineer, but would open it to a large class of students to whom much of the letter-press must now be "Greek."

While fully realizing, not only from the author's pleading, but from our own experience, the very decided advantage of the method here described, we are inclined to make the comparison between it and plane table-work rather less unfavorable to the latter. The author, we should say, gives too little weight to the advantage of field plotting as a guard against errors; and does not refer to the employment of a separate levelling instrument in the hands of a leveller who directs the rodman, which is so generally and so advantageously used in connection with the plane table.

The relative claims of the two methods are, however, as the author says, "a question every engineer must decide for himself," and we can heartily commend this book to the engineering fraternity both practitioners and students, as a highly satisfactory exposition of the subject. T. H.

A Treatise on Friction and Lost Work in Machinery and Mill Work. By Robert H. Thurston, A. M., C. E. New York: John Wiley & Sons, 1885.

This is one of the works that place the public under obligation to their authors. In it, Professor Thurston lays before us the abundant fruits of years, of intelligent and pains-taking study and observation. The present work covers the same ground as the author's earlier treatise,* but with much greater fulness, in general and in detail. It might indeed have been, with propriety, and to the improvement of its title, announced as a greatly enlarged edition of the former work.

The first chapter is a brief glance at the general theory of machinery, including force, power, work, energy, efficiency and lost work.

The second takes up the theory of friction in detail, giving special prominence to the friction of journals and pivots, but embracing also that of wedges, pulleys, wheels, earth, etc., and of fluids.

* "Friction and Lubrication," published by *The Railroad Gazette*, New York, 1879.

The third is an exceedingly satisfactory description of the lubricants themselves, animal, vegetable and mineral; solid, semi-solid and liquid, with their several excellencies and defects, their most frequent adulterations, etc.

The fourth is devoted to the very important subject of the methods of applying lubricants; upon which, more perhaps than upon any other feature, the value of lubrication is shown to depend. The various methods in use are described, and their respective merits and demerits discussed. Strangely enough, we find but a very incomplete description (without cuts) of the *oil-bath*, which is frequently referred to throughout the book as being by far the most perfect device for reducing friction.

The fifth chapter is an eminently practical treatise upon the testing of lubricants. It is full to the brim with most useful tabular and other information. It should, we think, as a matter of arrangement, have contained the description of the author's pendulum testing machine. This, with similar accounts of other machines, we find, rather out of place, in the sixth chapter, along with the recital of many of the earlier and later experiments on friction.

The seventh chapter is exceedingly valuable; giving, as it does, the behavior of all sorts of lubricants under all sorts of conditions, as determined by the most recent and exhaustive experiments, mostly made by the author with the testing machines designed by myself and already referred to. Many of the results here announced are quite at variance with those published by earlier experimenters; particularly in the matter of the effect of pressure. The author found much higher coefficients under low pressures, and much lower ones under high pressures, than did his predecessors; and, generally, much greater variations of the coefficient with pressure, velocity and temperature. Most interesting diagrams are here given, showing the effects of these three elements upon the coefficients obtained with a given lubricant; and their interdependence upon each other.

The eighth, and last, chapter, a bright one, proposes a theory of the finance of lost work, and a method for the determination, by formulæ, of the commercial values of lubricants. It is not denied that the difficulty of obtaining the required data for these formulæ is very great, and at times insurmountable; but where these can be approximated with confidence, the use of the formulæ (which are quite simple) ought to lead to important economies.

The index is rather meagre, but is admirably arranged, both the number of the *article* and that of the *page* being given for each subject.

If there is a fault in this work, it arises from the intimacy of the author's acquaintance with his subject, which seems to lead him at times to forget the necessity for extreme care as to the way of stating things. As a good lubricant may, through a faulty method of application, fail to give its best results, so even the bountiful feast of reason which the author here spreads, might, we think, have been made more inviting by closer attention to detail in the serving up. Merely as an instance, we note the following sentence on page 139: "Economy is best secured where the dripping oil is not preserved by any arrangement which furnishes the lubricant in a perfectly uniform supply and in minimum safe quantity." True, the reader soon finds that commas (or, still better, the old-fashioned parentheses) are needed after "secured" and after "preserved," but the meaning would have been plain at once if

the sentence had begun with the parenthetical clause, "where the dripping oil is not preserved." These little matters often make the difference between a readable book and a "tough" one.

But where the recognized authority upon a difficult subject like this, gives to the fraternity so solid a mass of valuable fact as in this case, it is hardly in order to cavil over details; and we have no doubt the fraternity will substantially express its obligation by eagerly using what is set before it.

T.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, September 16, 1885.*]

HALL OF THE INSTITUTE, September 16, 1885.

MR. WM. P. TATHAM, President, in the Chair.

Present—Fourteen members.

The election of forty new members was reported.

The Secretary reported a recommendation from the Committee on Science and the Arts, for the award of the JOHN SCOTT Legacy Premium and Medal to P. E. JAY, of New York, for his Automatic Anti-Freezing Valve for Water Pipes. The recommendation was approved, and the Secretary was directed to inform the Committee on Minor Trusts of the Board of City Trusts of the action of the INSTITUTE.

No programme of business having been arranged on account of the opening of the "NOVELTIES" Exhibition, the meeting was thereupon adjourned.

WILLIAM H. WAHL, *Secretary.*

[*Proceedings of the Stated Meeting, held Wednesday, October 21, 1885.*]

HALL OF THE INSTITUTE, October 21, 1885.

MR. WM. P. TATHAM, President, in the Chair.

Present—Sixty-one members.

The election of thirty-two persons to membership was reported.

The Chairman of the Committee on Science and the Arts reported the following recommendations for the award of the JOHN SCOTT Legacy Premium and Medal; viz.:

JOHN H. DOERR, WILLIAM H. WIGMORE, of Philadelphia, } for their improvements in Sleeping Cars.

SAMUEL WILLS, Camden, N. J., for his improvement in Journal-bearings.

CYPRIEN CHABOT, Philadelphia, for his Straight-Needle, Waxed-Thread Sewing Machine, for Sewing Shoe Soles to Uppers.

CYPRIEN CHABOT, Philadelphia, for his Machine for Channeling Shoe Soles.

CYPRIEN CHABOT, Philadelphia, for his Sole-Edge Turning and Bending Machine.

FRED'K SIEMENS, Dresden, Saxony, for his Regenerative Gas Burner.

PAUL LA COUR, Copenhagen, Denmark, for his invention of the Phonic Wheel.

PATRICK B. DELANY, New York, for his improvements in Multiplex Telegraphy.

E. A. CALAHAN, Brooklyn, N. Y., for his improvements in Multiplex Telegraphy.

He likewise reported the following recommendations for the award of the ELLIOTT CRESSON Gold Medal of the INSTITUTE:

FRED'K SIEMENS, of Dresden, for his Regenerative Gas Burner.

PATRICK B. DELANY, New York, for his improvement in Multiplex Telegraphy.

CYPRIEN CHABOT, Philadelphia, for his Stright-Needle Waxed-Thread Sewing Machine, for Sewing Shoe Soles to Uppers.

The above recommendations were separately taken up in the order named, and were each unanimously adopted. The Secretary was directed to take the customary steps in connection with the same.

The Secretary presented his usual report of progress in Science and the Arts, whereupon the meeting was adjourned.

WM. H. WAHL, *Secretary.*

[*Proceedings of the Stated Meeting, held Wednesday, November 18, 1885.*]

HALL OF THE INSTITUTE, November 18, 1885.

WM. P. TATHAM, President, in the Chair.

Present—146 members and eight visitors.

The Actuary reported the election of sixty-six persons to membership; and the following preamble and resolutions, adopted at the meeting of the Board of Managers, held Wednesday, November 11, 1885, viz:

Whereas, Valuable service has been rendered to the FRANKLIN INSTITUTE, in conducting a series of Tests on Dynamo Electric Machines and on Incandescent Lamps, which tests were ordered by the Board of Managers; and,

Whereas, Said service was given without compensation, and required a large amount of labor and time;

Therefore,

Resolved, That the Board of Managers nominate the following named gentlemen for election to honorary membership in the INSTITUTE, for their invaluable services in conducting the electrical tests, under appointment by the President, viz.:

LOUIS DUNCAN, Ph. D., Ensign U. S. N.

JOSEPH B. MURDOCK, Lieut. U. S. N.

WILLIAM D. MARKS, Whitney Prof. of Dynamic Engineering, University of Penna.

GEORGE L. ANDERSON, Lieut. U. S. A., Instructor of Mathematics, U. S. Military Academy, West Point, N. Y.

A. B. WYCKOFF, Lieut. U. S. N., Philadelphia.

GEORGE M. WARD, M. D., Philadelphia.

The gentlemen above named were thereupon unanimously elected as Honorary Members.

Professor E. J. HOUSTON made some remarks on Photography by the Lightning Spark, and on the Duration of the Lightning Spark, which have been referred for publication.

Mr. H. R. HEYL, Director of the late "NOVELTIES" Exhibition, made an oral report on the same. He stated in substance that the attendance numbered 145,000; that the cash receipts were about $43,000, and that, though it was yet too early to present a detailed financial statement, enough was known to make it safe to say, that the Exhibition had proved a financial success.

Mr. HUGO BILGRAM made some remarks on the supposed Polarization of the Electric Arc Current, which are referred for publication.

On the invitation of the President, Mr. BURNET LANDRETH, of Philadelphia, introduced Mr. JOHN ROBINSON WHITLEY, of London, Director-General of the American Exhibition, which it is proposed to hold in London in the year 1886. Mr. Whitley explained the character of the project above named.

The Secretary's report embraced remarks on the great extension of the use of Natural Gas in Pittsburgh and Vicinity; on the Present Prospects and Condition of the Panama Canal Enterprise; on the Phelps' System of Telegraphing to and from Railway Trains in Motion; on the Diehl Electric Motor; on the Fahnehjelm Incandescent Burner for Water Gas and similar Non-luminous Gases; and on Dr. F. V. Greene's Process of Extracting Oil from the Refuse of the Starch Manufacture, etc.

Adjourned. WM. H. WAHL, *Secretary.*

PRODUCTION OF LOW TEMPERATURE.—Wroblewski used liquid ethylene by means of which a temperature of — 152° can be obtained. He measured the temperatures by the aid of a galvanometer and a thermo-electric couple of copper and german silver. Under the ordinary atmospheric pressure, oxygen boils at — 181·1, and nitrogen at — 193·2°. The vapor-tension of liquid nitrogen is 32 atmospheres at — 146°. Carbon monoxide boils at — 190° under the atmospheric pressure. The critical pressure of oxygen is about 50 atmospheres, and the critical temperature about — 118°. Liquid atmospheric air boils between — 187° and — 191·4° under a pressure of 740 mm., but the liquid loses nitrogen on boiling, and its boiling point gradually sinks. Under the pressure of 20 mm., oxygen boils at — 200·4°. Nitrogen boils at — 203° under a pressure of 65 mm., and solidifies to a crystalline mass. Carbon monoxide easily solidifies at — 199°. The tension of its vapor at this temperature is equal to 100 mm. As the readings of the hydrogen thermometer cease to agree with the results calculated by the aid of the galvanometer at this temperature, it is probable that hydrogen approaches its point of liquefaction at — 200°.—*Jour. Chem. Soc., July, 1885.*